▪ *MAKE BELIEVE NUCLEAR BLASTS* ▪ *ARTIFICIAL SKIN COMES ALIVE* ▪

Technology Review

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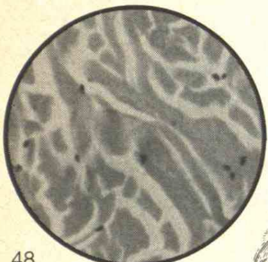

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Cover illustration by Anthony Russo
Design by Nancy Cahners

SCIENCE/SCOPE

The first attempt to sample the atmosphere of an outer planet, NASA's Project Galileo will journey 750 million miles to Jupiter this decade. The mission will consist of two spacecraft, an orbiter and a Hughes Aircraft Company-built probe. Six instruments inside the probe's descent module will assess the structure and composition of the atmosphere, determine the location and structure of clouds, calibrate a precise ratio of hydrogen and helium, and measure lightning, radio emission, and energy absorption. The probe will transmit data to the orbiter for relay to Earth. Project Galileo will be the first interplanetary vehicle launched from the space shuttle. The launch is set for May 1986 and arrival for August 1988. Four Hughes-built probes explored the atmosphere of Venus in 1978.

The sights, sounds, motion, and urgency of combat await pilots who learn to fly the F/A-18 Hornet strike fighter in the first computerized simulators of their kind. A pilot wears full flying gear and sits in an exact replica of an F/A-18 cockpit located inside of a 40-foot-diameter sphere. High-resolution pictures of earth, sky, and targets are projected onto the inner surface of the sphere and matched with sounds and vibration. Pilots experience runway vibration, aircraft stalls, buffeting, missile launches, cannon fire, dazzling aerial maneuvers, and aircraft and missiles approaching at supersonic speeds. The Hughes simulator will save the U.S. Navy and Marine Corps millions of dollars by providing combat training without costly flight operations.

Defects in printed circuit boards are spotted quickly and accurately with a color graphic display in one Hughes manufacturing division. Digital information from the computer-aided design of boards is processed before testing begins to create exact images of board topography. Automatic equipment identifies circuit faults and notifies a central computer. If the computer detects a failure trend, it will include an advisory in the test report so defective processes may be investigated. The test data file is then sent to a computer-graphics work station. There the board image is displayed, with each fault area shown in contrasting color. Hit-or-miss troubleshooting is thus eliminated.

A trio of multipurpose communications satellites has been introduced by Hughes to handle standard communications and direct TV broadcasting to homes. All three are drum-shaped and spin-stabilized. One model, designated HS 393, is the domestic communications satellite of the future. It can carry 16 high-power channels or 48 channels at lower powers. A second spacecraft, the HS 394, has a flat, sun-tracking solar array, thereby combining the best features from the existing technologies of spin-stabilized satellites and body-stabilized satellites. The third model, the HS 399, is a small spacecraft with 12 channels. Occupying only one-fourteenth of a space shuttle cargo bay, it could be launched for about one-third the cost of orbiting a standard 24-channel satellite.

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FIRST LINE

Humanism in Technology

This is the third issue of *Technology Review* whose contents are shared with *Beruf*, a Japanese-language journal of new technology published in Tokyo.

In welcoming *Beruf*'s 80,000 readers under the exclusive Japanese rights that its editors negotiated with us, we wrote, "Most of us take for granted the benefits to our prosperity and comfort brought by science through the mechanism of technology. But we are learning that technology is not neutral; it often brings significant (and sometimes unexpected and undesired) changes in human affairs and the environment in which they are conducted. It is to the understanding of these effects, and the decisions that we must make to moderate and manage them, that *Technology Review* is dedicated."

An example of how this posture governs the *Review*'s editorial decisions is in this issue—the series on the growing role of automated machines in American industry. Marjory Blumenthal and James Dray describe automation technology, Harley Shaiken suggests how workers and robots can most fruitfully share the tasks of production, and Jonathan Schlefer reports on union negotiations over a factory of the future in Lynn, Mass.

Quite by chance an eloquent plea on these issues came to us from an engineer just as this number of *Technology Review* was being assembled. Speaking to an audience of fellow alumni of M.I.T., Professor James D. Ham, former president of the University of Toronto, said, "The alumni of a great institute of technology have a special responsibility to consider and to speak out on the public issues that surround the place and character of work in our society. . . . There is challenge for us to take off our blinkers about men and women and work to think fundamentally about the nature and meaning of work amid radical technological change. A true humanism for enlightened engineering may yet be found in a profound concern for the nature of the work we require others to do."

At about the same time, Frank Press, president of the National Academy of Sciences, was bringing to an M.I.T. audience an outspoken tribute—an epiphany, he called it—to the "new industrial revolution based on advances in science and technology. . . . Science and technology are our nation's strongest card," Press said.

There need be no sense of ambivalence here, for surely both Ham and Press would join the *Review* in judging that technology can be strengthened by humanism even as humanity is strengthened by technology.—*John Mattill*

LETTERS

Breaking the Inflationary Cycle

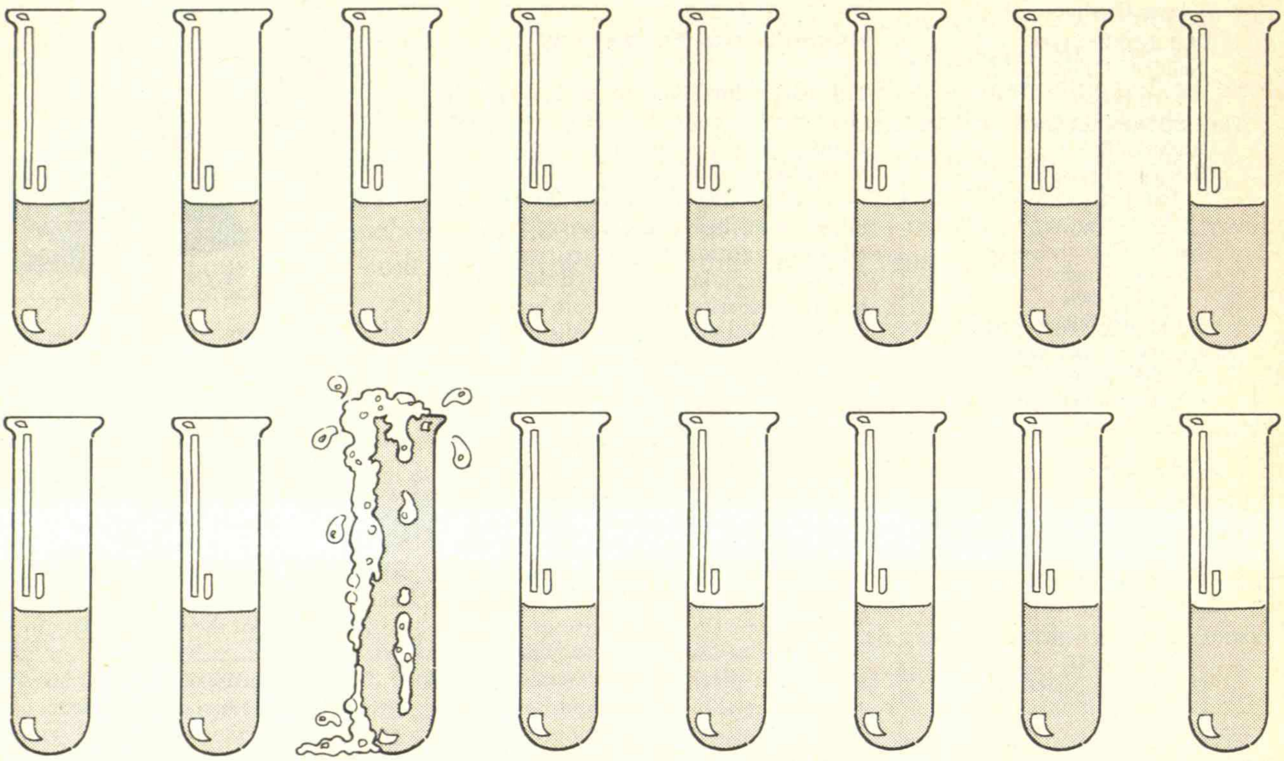
Thurow's simplistic statements about the cause of inflation in "Preventing the Eleventh Recession" (*July, page 6*) show how much we can trust an economist's view. His argument—that when the value of the dollar drops, Americans must spend more money on expensive imports and thus have less money to buy U.S. goods and services—at first seems logical and persuasive. If one follows through this reasoning, however, its fallacy becomes obvious.

The United States could be self-sufficient in most commercial items, importing only a few raw materials that are in short supply here. For instance, we import Japanese cars only because they are relatively cheap and well-made. If their dollar prices rose by 50 percent, the American public would revert to buying American cars. Furthermore, the U.S. economic engine is such that it can quickly respond to real market demand, provided that government does not meddle needlessly with the economy. Adam Smith's invisible hand is still a powerful force in the U.S.

Francis de Monterey
Hopkins, Mich.

Thurow recommends that we avoid inflation by indexing wages to the value added per hour of work, since this fluctuates with the price of imported materials. However, this would seriously

What makes our science park so different from the others?



To start with, ours is in Scotland, a country with a world-wide reputation for innovation and development.

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Where more silicon chips are manufactured per capita than in Japan.

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SCIENCE PARK

Contact: Dr Colin Bond at 1.01 Kelvin Campus, West of Scotland Science Park, Glasgow G20 0SP. Tel. 041-946 7161.

hamper collective bargaining, calculations of employee benefits, and other wage variables that help legitimize capitalism. Such a linking would also complicate the regulatory system and require accountants to grapple with definitions of sales revenue and materials costs—concepts that are already difficult to define.

The value-added scenario is not the route to full employment without inflation. Rather, full employment can be reached by finding ways to better extract and develop natural resources and control their costs. Manufacturers can use strategic planning, materials planning, and quality assurance to reduce production costs and provide quality goods that last longer. This in turn slows consumption, provokes more investment, and, ultimately, retards inflation.

E. George Pierce
Boston, Mass.

Putting a Price on Life

As advances in medical technology increase the average lifespan, there will be more elderly needing more health care (*"The Controversy over Commercialized Medicine," April, page 10*). Thus, even if medical fees are "frozen," the nation's medical bills will keep mounting.

Only older people can dare suggest limiting insurance payments—whether public or private—for medical procedures, and to lower this limit as each year goes by. Perhaps the limit at 75, for example, should be half that at 65, and the limit at 85 halved again. I am not bold enough to say at which age it should reach zero. But there has to be some ultimate limit to the total cost of health care. Under such a system, the young lives protected by a strong program of preventive medicine would have more value than those lives prolonged by expensive medical technology.

E. Scott Pattison
Dunedin, Fla.

Confusion over CO_2

In "The CO_2 Threat: Solutions Welcome" (*April, page 8*), Robert Cowen suggests that EPA released its report entitled "Can We Delay a Greenhouse Warming?" last October to "preempt public attention from a National Academy of Sciences report on the subject." Cowen also claims that the former report was alarmist, the

Continued on page 77

ROBERT C. COWEN

Payoffs of Long-Term Weather Forecasts

LONG-RANGE weather forecasting has been an exercise in near frustration. Until now, its practitioners could only claim a marginal degree of skill and hope to do better one day when they had a firmer scientific grip on the problem.

Now that day appears to be dawning. Fast modern computers running improved mathematical models of the ocean-atmospheric system promise to put a firmer foundation under an art that has been based on assumption and uncertainty. Growing understanding of how soil moisture, sea surface temperatures, and other "boundary" conditions regulate the atmosphere may put more skill into regional forecasts of average temperatures and precipitation of a season or more in advance.

In short, according to Alan D. Hecht, head of the National Climate Program Office of the National Oceanic and Atmospheric Administration, the opportunity exists for high-leverage investment in research on long-term forecasting.

This investment could pay off in significant cost savings as well as in scientific knowledge. For example, Samuel I. Hyman of the Brooklyn Union Gas Co. says that forecasts of extreme temperatures three to six months in advance could save "substantial sums" for the gas industry. However, he adds that the forecasts would have to be at least 75 percent reliable for the industry to realize such savings.

At that level of reliability, potential annual savings in other areas such as agriculture could run to many billions of dollars. Ray Daniel of Chase Econometrics notes that if planners had known that drought would reduce corn farmers' production by a billion bushels in 1983, they could have saved $20 billion on the Payment-in-Kind program, which encourages farmers to keep land out of production. Similarly, Deputy Secretary of Commerce Clarence J. Brown points out that the United States sustained some $500 million in weather-related agricultural losses during the abnormally warm winter of 1982-83, which brought torrential rains and severe flooding to the West Coast. These losses could have been reduced if mete-

Seasonal weather predictions could soon save the nation billions of dollars.

orologists could have predicted the climatic anomaly more reliably.

No meteorologist can promise to achieve a given degree of reliability in long-range forecasting. But new investigation could bring substantial gains over the next five to ten years. To focus attention on this opportunity, the American Meteorological Society joined Hecht's office in sponsoring a Climate Prediction Workshop in September.

Forecasting El Niño

According to Richard Sommerville of Scripps Institution of Oceanography, short-range forecasting is solidly based on a mature technology of computer forecasting. These forecasts, based on known physical laws regarding the behavior of fronts, air masses, and storm systems, have track records dating back to the 1950s.

Scientists don't ever expect to achieve long-range forecasts similar to these detailed predictions available on the evening news. That kind of forecasting is probably limited to two to three weeks, according to Jagadish Shukla of the University of Maryland. Yet the prospect of being able to develop more realistic long-term models using faster computers gives scientists new hope. This is partly because, thanks to global weather satellites, it is now possible to get data on boundary conditions almost in real time. Furthermore, said Shukla, forecasters are now at a stage to investigate how much potential predictability there may be in the internal dynamics of the atmosphere.

So far, researchers have found only two long-term phenomena that can be modeled, according to John M. Wallace of the University of Washington. One is the kind of extended drought that occurs summer after summer over a large area. The United States has experienced such an effect in this century only during the Dust Bowl droughts of the 1930s.

The other effect is the so-called El Niño/Southern Oscillation (ENSO). This is a coherent pattern of atmospheric pressure, sea surface temperature, and rainfall fluctuations long known in the tropical Pacific Ocean. When a period of abnormally warm sea surface temperatures—called El Niño—occurs, weather is affected around the globe. In particular, an ENSO can influence winter weather over North America, as it did during the winter of 1982-83. This is because heating of the equatorial Pacific sets up a wake of high- and low-pressure anomalies in the atmosphere. These act as obstacles to the general westerly wind flow even in northern latitudes. Wallace and his coworkers think that if they can model such effects, they could make useful predictions in early September for January and February, for the area from Seattle eastward to Minneapolis and the Southeast.

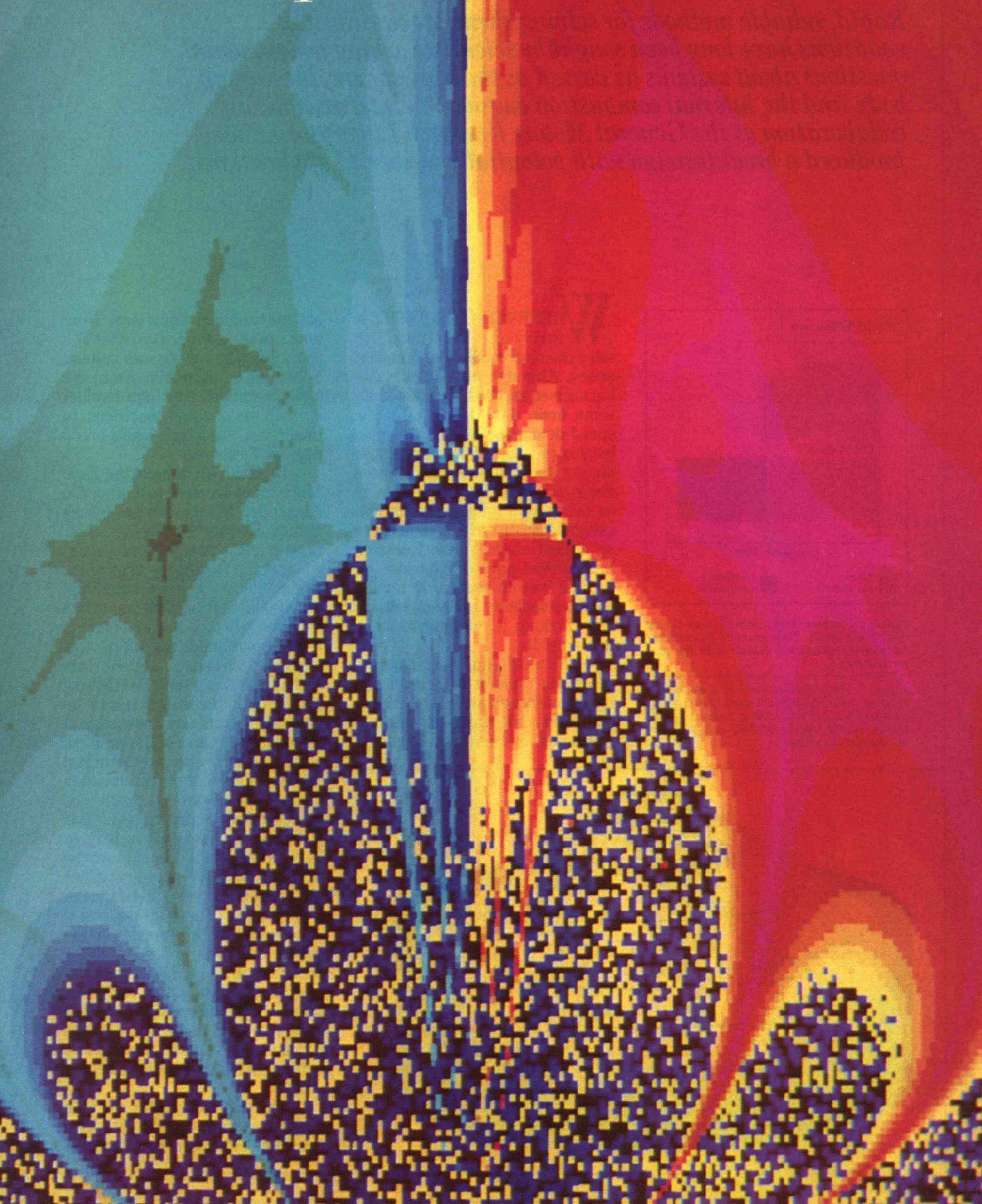
But the Commerce Department's Brown complains that government agencies have yet to realize that predicting seasonal weather extremes is becoming feasible. This makes obtaining funding for such research difficult. Hecht estimates that total federal support runs to about a million dollars—a level he considers an order of magnitude too low. "We have something exciting here," he said. "Why don't we get off the dime?"

The answer probably lies in the fact that, until recently, experts generally warned against expecting any breakthrough in long-range forecasting. It will take time for the bureaucrats to adjust to scientists' new perspective. □

ROBERT C. COWEN IS SCIENCE EDITOR OF THE CHRISTIAN SCIENCE MONITOR *AND FORMER PRESIDENT OF THE NATIONAL ASSOCIATION OF SCIENCE WRITERS.*

ILLUSTRATION: CHRISTOPHER BING

The Equilibrium Solution



The Equilibrium Solution

Rapid, reliable methods for solving chemical equilibrium equations have long been sought by scientists asking fundamental questions about systems as varied as the atmosphere, the human body, and the internal combustion engine. An interdisciplinary collaboration at the General Motors Research Laboratories has produced a breakthrough with potentially universal applications.

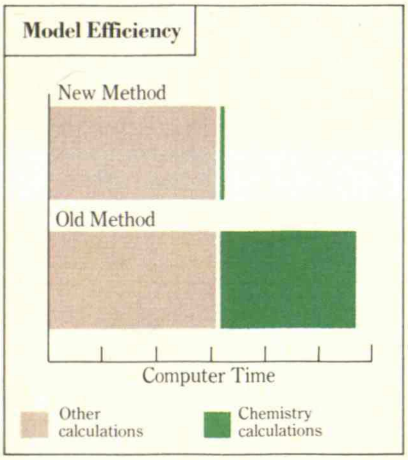
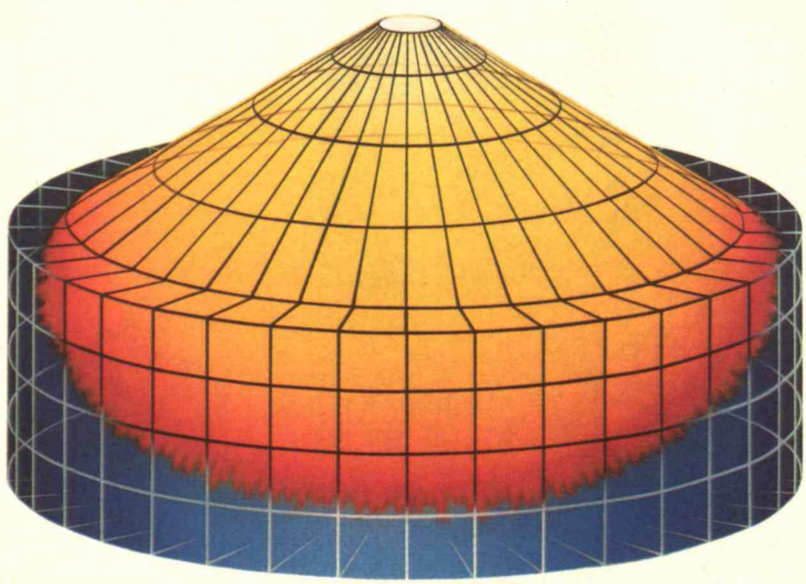


Figure 1: Computer time required by an engine combustion model. Time required for chemical calculations decreased greatly with the new methodology.

Figure 2: Artist's illustration of a chemically reacting flow. The physical space is divided by a latticed network into units of volume, and the solution must be recalculated for each grid point at each instant of time.



WHEREVER CHEMISTRY is involved, the need to solve chemical equilibrium equations arises. Although methods for solving such equations have existed for some time, they do not offer the speed demanded by the most challenging problems. For example, predicting the composition of gases inside an engine cylinder may require as many as a million equilibrium calculations per cycle. Two researchers at the General Motors Research Laboratories have developed a systematic way to reduce the mathematical complexity in these problems, thus making it possible to solve them rapidly.

Chemical equilibrium occurs when the rates of a forward and reverse reaction are equal. Mathematically, this statement usually translates into a system of nonlinear polynominal equations. Until now, there has been no fast reliable method for solving such systems. Solutions to particular problems have demanded thorough familiarity with the physical conditions. In most cases, this means partial knowledge of the answer.

Dr. Keith Meintjes of the Fluid Mechanics Department and Dr. Alexander Morgan of the Mathematics Department began their research by considering recent advances in the theory of continuation methods. They concluded that a suitable continuation algorithm could be relied on to solve the nonlinear polynomial equations that make up chemical equilibrium systems. In this insight lies the realization that the solution can be obtained without any knowledge of the physical nature of the problem.

In seeking the most efficient implementation of the continuation method, the researchers discovered that chemical equilibrium equations can always be systematically reduced to a substantially simpler mathematical form. The reduced systems have fewer unknowns and a smaller total degree. The total degree of any system is the product of the degrees of each of its equations. Reducing the total degree makes a system easier to solve. A typical combustion problem with ten equations and total degree of 192 was reduced by the researchers to two cubic equations with a total degree of nine.

The reduced systems can then be systematically scaled to fit within the limits imposed by computer

arithmetic. The range of coefficients in chemical equilibrium systems tends to be too large or too small for the arithmetic of the computer. Consequently, the solution process can fail. By construction of an effective scaling algorithm, this arithmetic constraint can be eliminated. Suitably reduced and scaled, the equilibrium systems can then be solved reliably by the continuation method.

THUS, Drs. Meintjes and Morgan accomplished their original goal of developing an innovative reliable approach to solving chemical equilibrium equations. They also made a final, unexpected discovery. Certain standard solution techniques, which fail on the original systems, can be made absolutely reliable when applied to the reduced and scaled systems. These methods, which are variants of Newton's method, are also many times faster than continuation.

This research has produced an extremely effective solution strategy—reduction of the equations, followed by scaling of the reduced systems, followed by the application of a suitable variant of Newton's method. The simplification of the systems, which was originally formulated to facilitate the implementation of the continuation method, proved to be the critical factor enabling the use of fast techniques.

In one application, the chemical equilibrium calculations are part of a model which predicts details of the flow, turbulence, and combustion processes inside an engine. By using their methodology to develop an equilibrium solver for this application, the researchers greatly increased the model's solution efficiency (see Figure 1).

"It was the characteristic structure of equilibrium equations," says Dr. Meintjes, "that allowed us to perform the reduction. The unexpected mathematical simplicity of the reduced systems suggests that even more efficient solution methods may be discovered."

"Critical to this research," says Dr. Morgan, "was the dialogue between disciplines. I hope that this dialogue will continue as scientists and engineers in diverse fields explore the capabilities of this new methodology."

General Motors

MARK OF EXCELLENCE

THE MEN BEHIND THE WORK

Dr. Keith Meintjes, a Staff Research Engineer in the Fluid Mechanics Department, joined the General Motors Research Laboratories in 1980. Dr. Alexander Morgan, a Staff Research Scientist in the Mathematics Department, joined the Corporation in 1978.

Dr. Meintjes (left) was born in South Africa. He attended the University of Witwatersand, where he received a B.Sc. and M.Sc. From 1973 to 1975, he taught fluid mechanics and engineering design at the university. He then went on to study at Princeton University, where he received an M.A. and Ph.D. in engineering. His doctoral thesis concerned numerical methods for calculating compressible gas flow.

Dr. Morgan (right) received his graduate degrees from Yale University in differential topology. His Ph.D. thesis concerned the geometry of differential manifolds. Prior to joining General Motors, he taught mathematics at the University of Miami. His book, "Applications of the Continuation Method to Scientific and Engineering Problems," will soon be published by Prentice-Hall.

The Great Dollar Bubble: Hurting American Exports

THE U.S. balance-of-trade deficit is running in excess of $130 billion per year. To finance a deficit of this magnitude, the United States must borrow money abroad at a rate that will make it a net debtor nation—owing more to foreigners that it is owed by foreigners—by mid-1985. The United States hasn't been a net debtor nation since World War I.

The overvalued dollar—the cause of the trade deficit—is often portrayed as if it were just a financial problem. It is not. As debts owed by Americans mount, interest payments to foreigners eat up a larger and larger fraction of the goods and services Americans would otherwise enjoy. Industry and technology suffer. With costs far above those of their foreign competitors, industrial firms, high tech or low tech, find that they lose market share at home and abroad. Once lost, market share is hard to rebuild, since foreign competitors have established the service networks and developed the customer loyalty they previously didn't have.

With the rapid growth and high profits generated by capturing existing markets from American firms, foreign firms can afford to invest in new technologies that American firms, with their contracting markets, cannot afford. The financial resources to develop new products and production processes simply disappear. And even if the resources to invest have not disappeared, the incentives to innovate have. Any new investments would be quickly undercut by foreign competitors who could offer low prices. The result is a super-cautious business environment. Such an environment simply does not encourage risk taking and innovation.

Everyone understands that no nation can run a balance-of-trade deficit forever. Everyone understands that no one can borrow from strangers forever. Yet last fall the dollar did nothing but rise—reaching a seven-year high vis-à-vis the Swiss franc, a ten-year high vis-à-vis the Dutch guilder, an eleven-and-a-half-year high vis-à-vis the German mark, and all-time highs vis-à-vis the currencies of Britain, France, Italy, Denmark, Finland, Norway,

With the dollar overvalued, U.S. firms are losing markets and profits at home and abroad.

and Sweden. American exporters could sell little on world markets before the most recent jump in the dollar right after Labor Day, and they will sell even less with an even more overvalued dollar.

Economic fundamentals indicate that the dollar should be falling, yet it does nothing but rise. How can this be? There are two approaches to understanding such a conundrum. Those who believe in the all-wise virtues of financial markets search for rational factors that would justify a high-valued dollar. They point to rises in American interest rates. With a large differential between American and foreign interest rates, foreigners want to hold their money in the United States. To do this, they have to buy dollars and sell their local currency. They point to the fact that the American recovery is much faster than that in the rest of the world. Foreigners want to get in on the American boom. To do this, they have to buy dollars and sell their local currency. They point to political uncertainties in Latin America and much of the rest of the Third World. Such uncertainties lead to capital flows into safe havens such as the United States.

While there is probably a bit of truth in each of these suggestions, they just don't explain the magnitude and persistence of what has been going on. To understand why the dollar is so overvalued, it is necessary to think of the great financial bubbles—and ensuing panics—of the past. Leave the world of the rational and enter the world of the irrational.

The Tulip Craze

In 1633 Dutch speculators started to buy and sell tulip bulbs. Three years later, in 1636, individual bulbs were selling for hundreds of dollars. The Dutch were not stupid. Everyone knew that the bulbs were not "worth" hundreds of dollars and that prices would eventually fall. In the long run the value of bulbs could not be much greater than the costs of growing them. But people were willing to pay hundreds of dollars because they thought that bulbs would go even higher. They would be the smart ones who would make a killing and get out before the inevitable crash. But the crash came earlier than expected—in 1637. Most of the speculators were caught, their fortunes were swept away, and they were left in financial ruin. But note that it took four years for the rational facts about tulips to overwhelm the irrational beliefs about their worth.

The South Sea bubble was next, bursting in Great Britain in 1720. The value of the shares of the South Sea Co., a firm engaged in fishing and slaving, had been rising gradually over the previous seven years, but it exploded by a factor of ten in six months. In words of the time, the stock market became "a roaring Hell-porch of insane and dishonest speculators." The stock eventually crashed, wiping everyone out.

The Great Depression followed just such an "irrational" speculative surge. By 1929 a farm depression had been underway for several years and the nation's GNP had already ceased to grow, but the stock market continued to bound upward in ever-greater leaps until those fatal days in October. It took 10 years to clean up the resulting mess.

The current rise in the dollar ought to be called "the great dollar bubble." Everyone understands that the dollar is already

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ILLUSTRATION: EUGENE YELCHIN

too high and must inevitably fall. But everyone thinks that in the short-run the dollar must go even higher. They are the smart ones who will buy dollars today, sell their dollars tomorrow when their value is even higher, take their profits, and get out before they lose their fortunes. History teaches us that most of them will be wiped out just as such speculators have been wiped out in the past.

While no one could predict the day when tulip prices would crash in 1637, it does not take a genius to know that tulips are not worth hundreds of dollars. Similarly, while no one can predict the day when the dollar will crash, it does not take a genius to know that the dollar is not worth 1,800 Italian lira or 9 French francs. At those rates, the dollar is as overpriced in 1984 as the tulip was overpriced in 1637. But there is nothing like greed and the belief that you are smarter than everyone else to fog the minds of otherwise rational people.

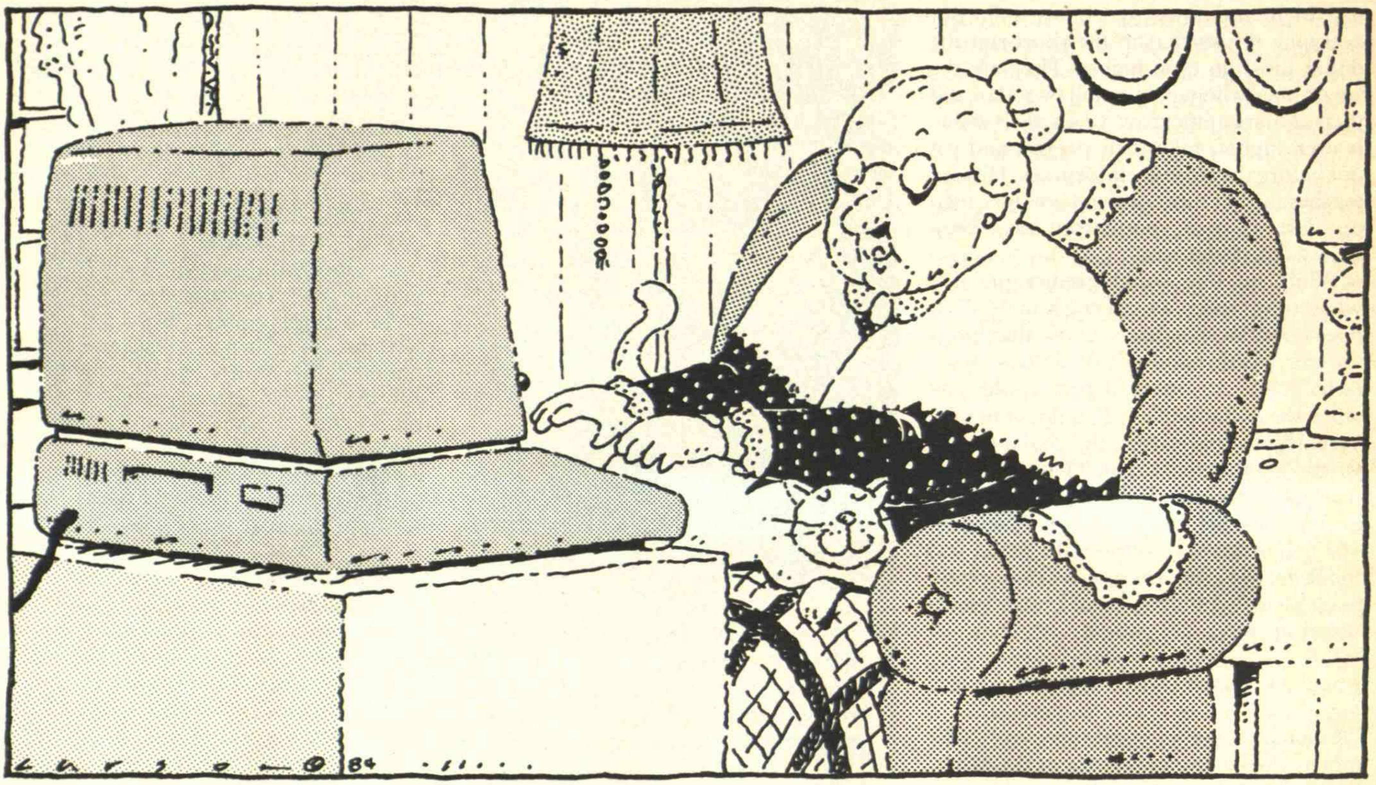
Knockout Punch

Of course, some financial types can make money on the ups and downs of the dollar. But industrialists can only lose. Markets and profits simply dry up. American firms could begin to market goods produced abroad under their label, but that is simply a decision to start down the path toward going out of business. Initially foreign firms would welcome this marketing help, but eventually they would establish a customer base. At that point the foreign firms would cut American marketers out of the system and deal directly with their U.S. customers. Why should they share the profits?

The U.S. government can act to hold down the value of the dollar. No government can intervene to maintain the value of its currency above the equilibrium level—the level that produces a balance between exports and imports. Such a move would require selling foreign currencies, which the American government does not have in unlimited supply. But any government can push the value of its currency down to equilibrium. For the U.S. government, that would require buying dollars, which it has in unlimited supply. The Reagan administration has chosen not to do this because of its belief in the virtues of the free market. But in this case, the free market is aiming a knockout punch at American industry. □

BY SAMUEL GOROVITZ

Bringing Senior Citizens On-Line



A television advertisement shows a three-year-old sitting enthralled before the family computer as his father dutifully prepares him for life in the Information Age. There is a strong suggestion that to deny a child access to a computer is a modern form of child abuse—or at least a cruel cultural deprivation. Responsible parents are buying home computers by the millions. And school boards across the land are agonizing about how to acknowledge the computer age in their curriculum planning.

Many adults stand in horrified awe of the teenage wizards who roam almost at will around other people's electronic memories. Fast fortunes are made by programming protégés whose inventiveness leaves their elders dazzled. Troubled commentators ask what all this means for the future—what it portends for communication between youth and adults, for the development of moral integrity, for interpersonal relationships, for our sense of what it means to be human. We have entered the age of the computer, and the computer, it seems, belongs to the young.

At the same time, we are becoming increasingly aware that population demographics foretell a wholesale change in the fabric of American society. Today 11 percent of the population is over 65. In fewer than 50 years, that figure will climb to nearly 20 percent, and the number of people over 85 will triple. We have 13,000 centenarians in America today, some of whom are active and self-supporting. A generation from now, retirees will look forward as a matter of course to many decades of life, and people between 80 and 100 will form a much more significant segment of the population. No longer will contemporary culture be dominated by the hawkers of "the Pepsi generation." The Medicare and Social Security systems are already straining under the pressure of these changes, and the requisite social adjustments will pose many new challenges. The future, it seems, belongs to the mature—with a substantial piece of it belonging to the elderly.

It's a wonder nobody in the world of commerce has made any serious effort to put these two aspects of contemporary life together. They're a natural match. Computers have remarkable potential to enhance the lives of the aging, yet that potential has hardly been noticed within the computer industry. Perhaps the problem is that market surveys haven't shown a commercial potential great enough to motivate investment in such prospects. But if the demographers are right, that will surely change.

Of course, computer technology has already been used to mitigate medical problems faced by the elderly. Such applications include aids to sensory perception and computer-aided diagnostic techniques, some of which are quite imaginative. For example, University of Texas neurologists use computers to monitor the video-game performance of patients with Parkinson's disease; the results reveal the progression of the disease and the effectiveness of treatment. Computers have also helped the elderly lead safer and more healthful lives. Examples include alarm systems linked to fire and police stations,

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ILLUSTRATION: JIM CARSON

devices that monitor the home environment, and programs that analyze diets and plan menus.

A small number of older citizens—including a few in their nineties—have turned to programming as a hobby, or in pursuit of a postretirement career. For example, *Infoworld* recently reported that the Little House Senior Adults Community Center in Menlo Park, Calif., had an active computer club and was expanding enrollment in its computer classes.

My concern, however, is not with medical applications, nor with the ways well-functioning, mobile retirees can use computers much as the rest of us do. I am interested instead in what computers can do to fulfill the special informational needs of people whose functional abilities have been diminished by age, and whose mobility is restricted.

Maintaining Active Minds

Life for the very old typically lacks the diversity of earlier years. It becomes dominated, on one hand, by the basic needs of physical survival, and on the other by the need to handle information—be it talking with friends, keeping up with the news, providing an oral history within the family, reading Aristotle (as Oliver Wendell Holmes is said to have done on his deathbed in his nineties), or simply enjoying the pleasures of reminiscing. The revolutionary information-processing technology that surrounds us could be put to much better use in serving these interests, thereby helping elderly people maintain active and interested minds. Nothing is more crucial to the quality of life in their declining years.

Some people scorn the idea of great longevity, but I'm all for it. What motivates me is largely *curiosity*: I want to stay alive as long as I can to see what happens. Many elderly people, physically debilitated in various ways, nonetheless delight in the spectacle of unfolding events. There's good news and bad news, to be sure, but all in all, it's quite a show.

At the Hebrew Home of Greater Washington in 1982, Director of Human Services Shulamith Weisman provided modified computer games for 50 frail, elderly residents whose average age was 85. Her project was made possible by the loan of a computer from the Apple Corp., and by the donated efforts of a local programmer who adapted the software of four commercial games. He increased the size of the visual images and reduced the pace of the action to allow for slower response times. Weisman found that residents who used the games showed increased vitality, improved ability to concentrate, and greater interaction. The residents themselves seemed pleased with the project. As one observed, "If the whole world is going crazy over computer games, why shouldn't we get in on the fun?"

But I don't have in mind simply putting computer games in nursing homes. Books, magazines, and courses of all sorts could be made available on terminals, with the text appearing on the screen in the size of print and intensity of brightness and contrast best suited to the reader. Friends in different locations could play games of chess or checkers and otherwise interact by using terminals. Of course, new programs would have to be written to allow elderly users to adjust for deficits in hearing and vision. Some hardware modifications also might be needed, such as enlarged keyboards designed not for speed but for users who have little manual dexterity yet much patience.

Videotex systems linking individual terminals with information services, communication networks, and even travel agencies and retail stores could provide other needed resources. A particularly helpful software package would include special financial management programs for retired persons dealing with the complex interplay of Social Security, Medicare, investment income, pensions, taxes, and expenses.

The captains of high technology could probably multiply my examples tenfold. However, it will be difficult to distract them from the lure of more imminent markets—especially since the creation of specially tailored software for the elderly will require sustained investment in research and development.

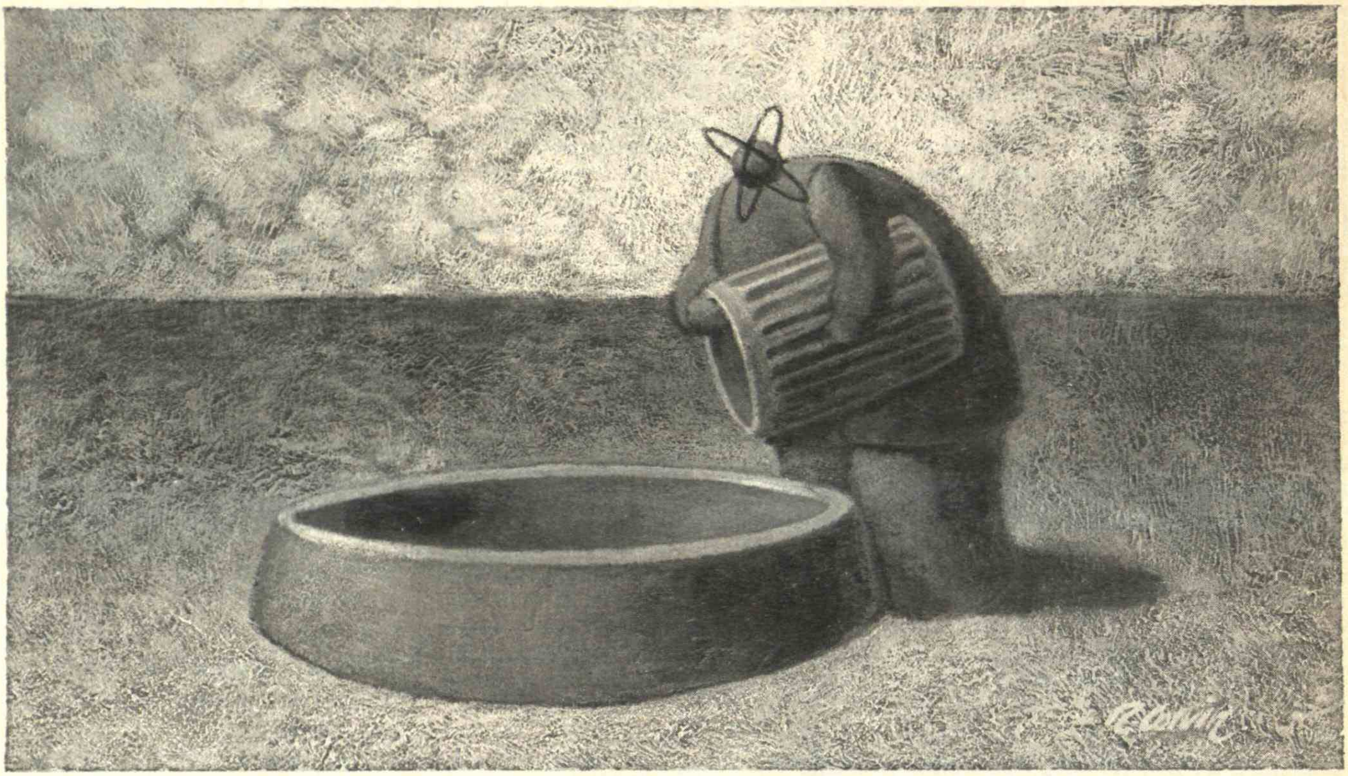
There is one bright light on the horizon. In San Francisco, psychiatrist Stuart Schwartz has just established Senior Software, Inc., a nonprofit firm devoted to developing applications of information technology for the elderly. Researchers from the company are planning to introduce various new computer programs into senior centers and study their effect on social interaction, self-esteem, and general psychological well-being of the residents. These activities may lead to a product line

Continued on page 76

FORUM

BY VICTOR GILINSKY

A Common-Sense Approach to Nuclear Waste



THE Achilles heel of nuclear power may turn out to be the lack of a satisfactory means of storing the highly radioactive spent fuel piling up at reactor sites around the country. Congress tackled the issue in the Nuclear Waste Policy Act of 1982, setting 1998 as the date when a deep underground repository could begin receiving used nuclear fuel for permanent disposal. After many years of vacillation, that action was to be a sign that the waste problem was finally under control. Unfortunately, the process of finding a suitable underground site has been delayed, and it is increasingly unlikely that the deadline will be met.

No aspect of nuclear power concerns people more than disposal of nuclear waste. In the case of deep underground disposal, this concern is underscored by uncertainties about below-surface geology, and what could happen over the long term to buried nuclear waste, as well as by the irrevocable nature of the decision. These public worries translate into demands for extraordinary precautions and siting standards so severe that it is unclear whether any site could qualify. We have taken on too great a burden in committing ourselves exclusively to a deep underground repository on a very tight schedule laid down by law. There is in fact no way of predicting when—if ever—we will have such a permanent disposal site.

One way out of this dilemma would be to build a surface or near-surface repository for semipermanent storage of nuclear waste. Such a facility would provide us with a safe means of storage while we continue to explore sites for permanent underground disposal.

Ironically, that is what the Atomic Energy Commission (AEC) concentrated its efforts on 12 years ago—developing a surface or near-surface repository. In fact, the AEC announced in 1972 that it would have such a repository available in 1979. Unfortunately, this approach was abandoned in 1975 by the newly formed Energy Research and Development Administration—for reasons not of health and safety but of psychology.

The conventional view then, as now, was that anything but permanent underground storage left proponents of nuclear power vulnerable to the charge that there was no "solution" to the waste problem. These advocates feared that, unless a permanent solution could be found, their opponents would find legal means to have plants shut down. Accordingly, the government shifted its goal to permanent underground storage, and all sides have since been obsessed with burying the waste, or at least showing that this could be done.

The key to success would be cooperation between the Department of Energy (DOE) and the six states, mostly in the West, who are candidates for a nuclear disposal site. However, officials in these states find that their constituents balk at accepting a waste disposal facility; they worry about potential problems such as contamination of underground waters and the proximity of proposed sites to national parks and recreation areas. The states intend to make full use of the Nuclear Waste Policy Act's requirements for state participation in site selection, and they do have clout. A state veto can be overriden only by a joint congressional resolution.

If the prolonged and sometimes bitter wrangling over step one in this process—preparation of guidelines for selecting underground sites—is a sign of things to come, we are in deep trouble. One of the most controversial issues has been

VICTOR GILINSKY is a former commissioner of the Nuclear Regulatory Commission.

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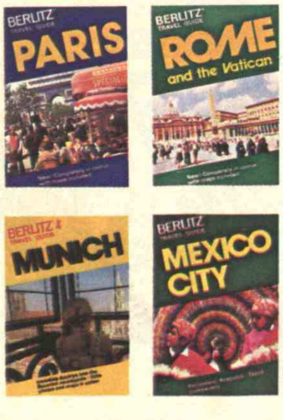

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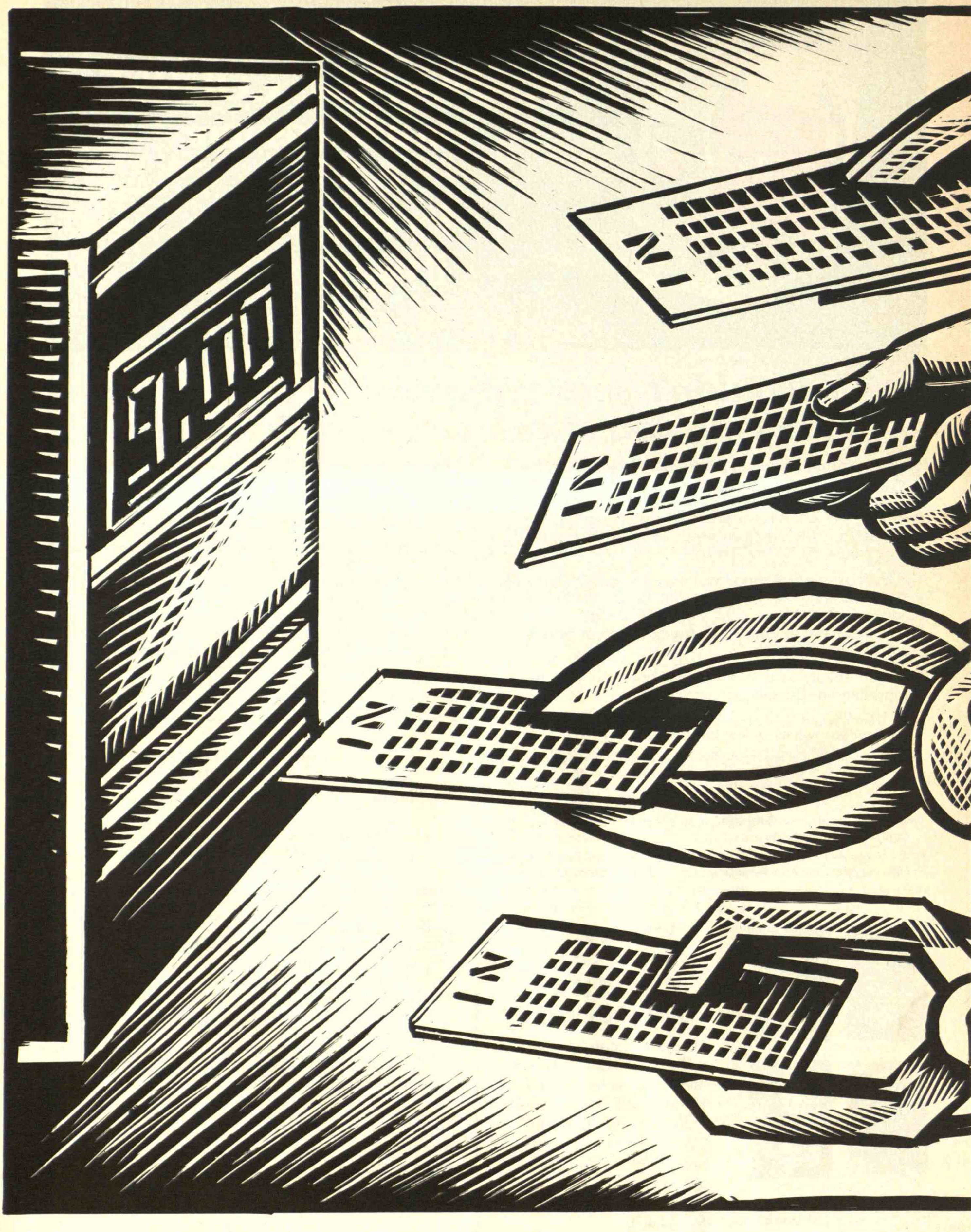

Using automation to eliminate human uncertainty only creates mechanical problems and degrades work.

The Automated Factory: The View from the Shop Floor

BY HARLEY SHAIKEN

As usual, at last year's International Machine Tool Show, held in the cavernous exhibition halls of McCormack Center on the edge of Lake Michigan, manufacturers displayed acres of computer-controlled machining centers, lathes, grinders, robots, and other automated equipment. These machines shape raw blocks of metal into the precision parts essential for any advanced industrial economy—from the parts that make up the wings of Boeing 747s to those used to build machines that package breakfast cereals.

The latest trend at the show, as throughout

ILLUSTRATIONS: ANTHONY RUSSO

Equipment never seems to break down at trade shows, but some automated factories are down a third of the time.

industry, is to use computers to link individual pieces of automated production equipment into automatic manufacturing cells, or even entire factories. Walking down the aisles in Chicago, you can envision vast plants operating under the control of a handful of skilled technicians. All that is needed to increase productivity spectacularly is to move these machines from the show to the factory floor. And no doubt workers will benefit from more satisfying high-technology jobs.

However, visions of automation that seem fine at machine-tool shows ignore the actual experience of supervisors and workers on the factory floor. To begin with, although computer-based technologies can indeed help make jobs more satisfying, that is often not what actually happens. In their attempt to create the automatically controlled factory, managers and engineers often wind up making jobs as tedious as those on the assembly line.

A skilled machinist I talked with who had been assigned to operate a computerized machine tool said he felt like a "rat in a cage." The machine had not eliminated his job—but was used in a way that degraded it by requiring little creative input. "You don't have time to light a cigarette," said a worker on a robotic welding system. "I'd take my old job hand welding any day."

Manufacturing systems never seem to break down at machine-tool shows, but I have visited automated factories that were down a third or more of the time. The cause is not hard to discover. Reducing human input often means instituting complex technologies that are prone to trouble. To put it another way, the drive to eliminate uncertainties arising from human influence only winds up creating mechanical and electronic uncertainties. Thus, despite the vision of total automation, workers must in the end play critical roles in operating, as well as unjamming and repairing, computer-based production systems.

Too often public debate centers simply on figuring out how to automate as rapidly as possible, rather than on finding ways to develop and install the best technology—one that both improves life on the job and provides efficient production.

Along with my M.I.T. colleagues Steven Herzenberg and Sarah Kuhn, I recently had the opportunity to explore the way automation affects worklife. As part of a project by the congressional Office of Technology Assessment to study computer-based automation in factories, we visited an automobile plant,

a commercial aircraft plant, an agricultural-equipment plant, and seven small metalworking shops. These firms differ in many respects, but all are leading and experienced users of automation.

We agreed not to divulge company names and in exchange were allowed a free hand to observe factories and obtain private interviews with everyone from top management to hourly workers. When I presented our findings to engineers who had actually designed many of the kinds of equipment we studied, some were surprised to learn about traps that they had not imagined would occur on the road to automation.

The Individual Machinist

Before the arrival of computer-based automation, the machinist's skill provided the missing link between a blueprint and a finished part. Using intricate fixtures and making careful measurements, machinists would orient parts to be machined in just the right way, and would then turn the necessary cranks and run the cutting tools.

In numerical control (NC), a computer punches holes in a paper or plastic tape, and when the tape is fed into a machine tool, these holes control the way it cuts metal. Most of the shops we studied used computer numerical control (CNC), a newer form of the technology in which a computer at the machine directly controls its operation. Both NC and CNC (the terms are often used interchangeably) can be far superior technically to manual control. The computer is able to guide the cutting tool through complex arcs and angles that no machinist could duplicate. Furthermore, intricate fixtures to hold parts at special angles are often unnecessary. Since all operations are preprogrammed, NC enables a machine to proceed from cut to cut far more rapidly than is possible with manual control, thereby reducing the time required to make a part. However, the machinist must still set up the workpiece to be cut, make adjustments to correct for tool wear, and stop the machine if anything goes wrong.

The technology of CNC leaves a wide latitude as to who programs the computer. At one extreme, a full-time parts programmer sits in front of a video screen and determines how a part will be made. At

Engineers who had designed computerized equipment were surprised to learn of problems they had not imagined.

the other extreme, a machinist does the same thing at a minicomputer at the machine.

There are sometimes compelling technical reasons for programming to be done off the shop floor. Devising long, complex programs may require intricate calculations taking several days. In other cases, it may be more efficient for machinists to write programs—particularly for making simpler parts. Operators at the machines are also especially well situated for debugging flawed programs. For example, in one shop we visited, a program called for making a heavy cut across a block of aluminum—an operation that generates considerable heat—and then boring two holes a precise distance apart. When the steps were carried out in this order, the distance between the holes decreased as the aluminum cooled. The machinist was able to correct the problem by editing the program to drill the holes first.

Managers in the small shops we visited organized production on CNC machines in different ways. In one shop, prototype machinists, who make the initial prototypes of parts, did the programming. Another shop rotated some machinists through the programming department. However, in the vast majority of cases, the responsibility for writing instructions for the machines had been removed from the shop floor and given to programmers working in offices, even when this was far from optimal technically.

Understanding why requires taking a look at owners' motivations in introducing CNC. They told us they introduced CNC partly to improve the machines' speed and flexibility, but also to tighten control over shop operations. By concentrating planning in the relatively small, white-collar programming department, they believed they could specify more uniform procedures for carrying out jobs. Also, since programmers are not responsible for actually running the machines, they have little incentive to use programming to slow the pace of production, the owners felt. As the officers of the Numerical Control Society, an organization of managers and engineers concerned with computers in manufacturing, wrote in 1981, CNC has put important decisions "in the hands of managerial and professional personnel rather than machine operators."

Shop owners were also concerned by what they saw as a shortage of skilled machinists and by the leverage of those who were available. "Five, six years ago, we were very dependent on skilled labor, to the point where I spent half my life on my hands and knees begging somebody to stay and do something," said one shop owner. "Machinists tend to be prima donnas. This is one of the motivations for bringing in NC equipment. It reduced our dependence on skilled labor." Another shop owner was so impressed by the power of CNC that he was considering firing most of his ten employees and starting over with a more amenable group. "Sometimes too much knowledge is dangerous," he said.

In practice, visions of firing the entire shop-floor workforce and hiring pliable new people off the street are probably not workable. Nor can CNC eliminate the need for machining skill somewhere in the production process. However, managers did report that this technology gave them more control in determining which jobs require that skill. They could employ machinists with considerably less expertise than that needed to run conventional tools—in effect moving that skill to the programming department.

However, using the lowest level of skill necessary to run CNC machines is not necessarily the way to make production most efficient from a technical standpoint—especially in machining small quantities of intricate parts. Not only can machinists contribute to programming; they must also often intervene in operations even after the program has been debugged, many owners admitted. An operator may find that the rough casting to be machined is larger than the programmer expected and thus requires more cutting. An alloy may turn out to be harder than expected, in which case the part must be fed more slowly into the cutting tool. "In a small business, when you invest a lot of money in a piece of NC equipment you don't want to save two dollars an hour by putting an unskilled operator on it," said one head of manufacturing engineering. "The higher the operator's skill, the more we get out of the machine."

The paradox is that, though skill and experience are required for operators of some CNC equipment, that very skill and experience may make operators dislike the equipment. Skilled machinists were particularly frustrated by CNC if they did no programming. "I'm a worker, not a sitter," said one. "I like to be kept busy. My day goes by faster, my mind is more active. You get a little weak-minded on NC."

"Machinists tend to be prima donnas," said a shop owner. "This is one reason for bringing in automation."

Another complained that CNC "was supposed to be made idiot-proof," and that he would rather quit than run such a machine full time. "The hardest thing to do is to keep yourself on your toes checking the measurements," said a machinist at the aircraft-manufacturing plant. "Just because the tape says the part is good doesn't mean that it necessarily is. But you get to relying on that tape because of the boredom. You know, you'd just as soon put another part in and sit down again."

Not surprisingly, managers do not find it easy to fill such jobs. "You'll find somebody who can do the job," admitted one shop-floor supervisor. "But once he's learned it, he'll get quickly bored and want to do something else."

It is true that machinists who formerly loaded hundreds of identical parts on conventional machines generally preferred CNC machines. The new technology tends to make work cleaner and physically lighter—not so much because of computer control as because of mechanical improvements. For example, workpieces are often shielded while being cut, preventing the dispersion of small metal particles and the cooling fluids that are sprayed on the cutting tools.

Skilled machinists, who had formerly planned production on conventional machines, told us that they would be more interested in using CNC machines if they had responsibility for writing programs. "Get a good operator and give him a chance to do setup and learn how to program the machine," said a machinist in a small shop. "That way he can look at the readout and understand what the machine is doing, not just stand there." The chance to program would not eliminate boredom during long running times or repeated production of a single type of part, but it would make jobs more creative and could increase productivity. Some machinists said that they already do some programming unofficially and felt that managers should give them formal recognition for it.

Spy in the Sky

CNC enhances managerial control in the workplace but does not make it complete. This technology affects only what happens when a part is actually being machined—and not, for example, how parts move from one production step to another through the shop. And machinists have a certain measure of control even while a part is being cut. They usually have a dial to override programmed feed rates (the rates at which workpieces are fed into cutting tools) to compensate for special factors such as unexpectedly hard alloys. Thus, operators can slow down or speed up the work pace.

To secure more control over this aspect of the machinist's job, and to better estimate the efficiency of the operation, the managers at the aircraft company implemented a computerized monitoring system on 66 NC machines. The system categorizes each machine as running, running at less than 80 percent of programmed feed rate, temporarily halted, or down. A panel in a control room above the shop floor displays the status of each machine with colored lights. A supervisor can check these lights and gain further information by glancing out at the floor below. Daily reports tell supervisors not only about production levels, but also about how each worker spends his or her time. Upper management receives weekly and monthly reports. Obviously, such a system has the potential to weave an electronic net of control through the shop.

Shop-floor workers generally tolerate the monitoring system, in part because of an agreement between the company and the union that the system will not be used for disciplinary purposes. Nevertheless, some operators told us that individual supervisors do use the system to exercise subtle discipline, constantly telling operators that their feed rates are too low. "It's like having a big television camera looking over my shoulder," said one machinist. The workers sardonically refer to the system as the "spy in the sky."

Management set up the system to ensure that the machines are operated at over 80 percent of the programmed feed rate. However, the system has no way of evaluating whether that feed rate was established correctly in the first place: the programmer could have set it faster—or slower—than was practical. And of course, if the rate is too slow, machinists have little incentive to raise it: since the programmers are so sure they are right, why not just let the machine poke along?

The information that the system produces may also be extremely misleading. One machinist told us that he had to work long and furiously to set up a particularly intricate part to be cut. As a result, his

"You don't want to save $2 an hour by putting an unskilled operator on expensive equipment," said a manager.

machine sat idle most of the day. While he felt that he had never worked harder, his supervisor reprimanded him because the system reported that his machine was idle.

The Domino Effect

A common managerial vision is to combine CNC machine tools, automated carts, robots, and other computer-controlled equipment into an entire production unit—a flexible manufacturing system (FMS)—that can run with as little human intervention as possible. An aspect of this vision was expressed bluntly in a survey report published in the September 1981 issue of *Iron Age*, a respected trade journal: "Workers and their unions have too much say in manufacturers' destiny, many metalworking executives feel, and large, sophisticated FMSs can help wrest some of that control away from labor and put it back in the hands of management, where it belongs."

One FMS we visited—in effect, a computer-controlled machine shop—produces transmission cases and clutch housings for a line of heavy-duty tractors. At one end of the system, workers load a large iron casting onto a chain-driven cart. Guided by computers, the cart carries this workpiece to one of 12 computer-controlled machine tools. Here it is unloaded, machined, reloaded, and shuttled off to another station. A complex formula ensures that the various operations are scheduled efficiently. Finally, workers unload precision-machined cases and housings—untouched, at least in theory, by human hands.

Three supervisors and 11 production workers are assigned to the day shift, fewer to the other two shifts. One operator is responsible for every three machines, changing tools when the computer indicates it is time, inspecting parts to be sure they are correctly cut, cleaning the area, and solving any problems.

The system is intended to minimize operator intervention—particularly in setting the pace of production. "You don't have people you're relying on," said the project manager. "Once the computerized system gets the part, it doesn't wait for a guy who is drinking a cup of coffee." Another manager noted that "quality is no longer dependent on the skill of an individual operator."

However, there is something of a dichotomy between what the managers of an FMS intend and what actually happens. Though the project manager spoke of not having to rely on people, he also admitted that operators must minister to this complex system with considerable "tender loving care." A tool may wear in such a way that it fails to cut accurately, or the boring head, which turns and maneuvers the cutting tool, may be slightly out of alignment. In both cases the operator has to make sensitive adjustments. Or a cart may jam and have to be unstuck.

Problems inevitably occur in such complex electronic systems, and when they do, they can spread in a domino effect. The planners of the FMS were able to limit this effect to some extent by designing the system with some redundancy. If one machining center goes down, the program and the part can be shuttled to another. However, it is hard to foresee all eventualities. Even the designers of the FMS expected that it might be down as much as 33 percent of the time. Managers' estimates of actual downtime, after the initial debugging period, range from an unbelievably low 4 percent up to 20 percent. Some workers told us that downtime was far higher than that.

Our own research team's experience at the plant, admittedly limited, suggested that downtime is a serious problem. While we were there, an air conditioner malfunctioned, causing a machine control to overheat and the machine to go down. This stopped the entire system. While it was down, the carts drifted slightly, and the computer lost track of their exact locations. Setting up everything again took three-quarters of an hour. On the following night the system was down for several more hours. Although managers scheduled work for the weekend to catch up, problems with the software caused that shift to be canceled.

High downtime does not necessarily imply that automated systems are unproductive. They work so fast when they are up that they do typically increase total output. However, high downtime does indicate that an automated system is falling short of its potential—a serious consideration, given the cost of the technology.

Upper management's response to the problem of downtime has not been to alter the technology or the organization of work, but to pressure supervisors to keep these complex mechanical and electronic sys-

Up to 80 percent of manufacturing engineers, who plan how parts proceed through production, could be eliminated.

tems working. The supervisors in turn pass that pressure down the chain of command. "They think you shouldn't make mistakes, so they come down hard," said an operator at the FMS. "After you make a mistake, you're so scared it gets so you can't do your work."

Robogate

The robotized welding system that we visited in the bodyshop of the automaker shed further light on some of these problems. Before robots were introduced, workers wielded heavy hand-held welding guns. The long black cables that connected these guns to overhead racks looked like vines and gave the body shop its nickname: the jungle. The welders working in this spark-showered jungle had some of the most unpleasant jobs in the plant. Thus, one might expect that using robots—programmable mechanical arms—to do the welding would improve the work environment even though it eliminated jobs. However, many of the 100-odd workers who remained on the new welding system disliked it because it had intensified the pace and eroded the quality of their worklife.

Under the new system, workers assemble the floor, sides, and some roof members of each car and secure them by hammering small metal tabs into slots, much as model tin cars are built. Then a gate, or large metal frame, cradles the body and holds it while robots weld it. This setup is referred to as a "Robogate" system. Mini-Robogates cradle and weld together subassemblies such as floors and sides before they are fed into the main line. Over 60 robots and other welding machines are employed in the entire operation.

Before the company installed the Robogates, workers welded some subassemblies at largely independent workstations. After they had completed the wheel-wells or other body parts, they could either place them on the main assembly line to be put together into car bodies, or store them in piles known as banks. This gave the workers some control over the pace of their work: to break the monotony of the day, they could push ahead quickly, bank a lot of parts, and then have some free time later on. Supervisors did not object to banking because it assured a continuous supply to the main assembly line even if unexpected problems occurred, such as a breakdown of the welding machines.

In contrast, the Robogate system ties subassembly workers directly to the line. They now operate welding machines working side by side with robots. There is no bank: when the subassembly is complete, they place it directly on the conveyor to the main line. The Japanese "just-in-time" concept, in which supplies arrive just before they are needed, is the theory behind this new approach. The company's director of manufacturing engineering argues that with fewer parts waiting to be worked on, defects are spotted quickly, and productivity increases.

However, managers have not considered the effects of these changes on workers. Almost every subassembly worker we spoke with complained about the hectic and sometimes erratic pace. "The work is lighter but faster," said one who was doing tabbing. "They want us to work like machines, too. But we're not machines, we're people." The new system also produces stress because of the lack of autonomy. The harried manager, stewing over decisions, is often considered the prototypical candidate for a heart attack. However, several studies, notably one by Robert Karasek at Columbia University, show that stress on the job stems not only from a hectic work pace but also from a lack of authority to make decisions.

Promoters of automation often claim that it broadens the scope of maintenance jobs. At both the tractor plant's FMS and the automaker's Robogate, maintenance jobs did indeed become more challenging. Workers told us that maintaining computerized control systems requires expertise in electronics and broader diagnostic skills than are needed for conventional equipment. However, automation puts those responsible for maintenance, particularly supervisors, under extraordinary stress, because a failure of one critical component could paralyze the system and even the entire plant.

The main Robogate line processes car bodies at the rate of more than one per minute, and any number of things can go wrong. The photocells installed to count car bodies may tell the computer to fit too many bodies into too little space. Then the carriers that transport the bodies along the line become jammed, and the robots sometimes keep on welding anyway. The scene that ensues resembles a crash on

"The ingenuity will be removed. The advantage will be in having fewer hiccups."

the freeway more than the effortless grace of automatic production.

The Robogate was initially built with storage areas capable of holding a two-hour supply of bodies at a number of critical points. But because the storage systems proved less reliable than the main system, managers told us they plan to eliminate them. Then, if the main robogate line goes down, the factory will be able to run for a short time. However, as soon as the storage capacity in the main line is exhausted, the entire bodyshop, with its millions of dollars worth of equipment and hundreds of workers, will stand idle.

The interconnected nature of the system puts tremendous pressure on repair crews. Welding-repair supervisors had an annual turnover rate of 150 percent in the first several years of operation. "This has been the hardest three years of my life," said a general foreman who has lasted longer than most. "There isn't any relaxation. I've walked out of here and sat in my car, unable to move, getting myself together."

Engineers Next

Computer technology can be used as a powerful tool to restructure the jobs of engineers as well as production workers. We discovered this in our visits to the manufacturer of commercial aircraft, a subsidiary of a larger aerospace firm. Only about one-third of the division's 40,000 employees actually "touch" the aircraft during production. Management plans to revamp most of the remaining two-thirds of the jobs through automation.

Engineering is now organized so that knowledgeable people in various departments and levels make decisions, communicating in meetings and by exchanging drawings. For example, the design engineer sends a blueprint of a part to the tooling engineer, who is responsible for figuring out how to make the devices to hold intricate aircraft components during production. The tooling engineer then generally modifies the design engineer's drawing and sends it back for checking. "All the engineers add their thoughts," said one manager. "Everybody is innovative. You end up with a product touched by a lot of people."

Introducing computer-aided design (CAD) systems, in which engineers work on computer terminals and video screens rather than on paper, need not mean changing this organizational structure. However, the aircraft company we visited is using computers to give elite engineering teams greater control.

Such teams will soon establish the basic design of an airplane and feed it into the computer system, along with fundamental decisions about tooling and manufacturing. This information will be launched throughout the rest of the company via the CAD network. Tooling and manufacturing departments will still be necessary, but only to work closely with the elite team in fleshing out the details of decisions that have already been made. One manager sees this system as "putting the smarts up front."

The design teams at the source of this stream of information will have broader responsibility, but, for a given volume of work, as many as a third of the engineers and technicians downstream are likely to find their jobs eliminated. Up to 80 percent of the manufacturing engineers, who plan how parts proceed from step to step during production, could be eliminated, according to company officials. And the downstream jobs that remain will be more constrained. "Many of the people who are left will be elements in a very controlled process," said the co-director of the computer-integration project. "The ingenuity of the craft will be removed. The advantage will be in having more consistent outcomes with fewer hiccups."

However, removing the hiccups without sacrificing creativity may be difficult if not impossible. "If you carry a process like this too far, you tend to suppress new ideas," said a former vice-president of engineering. "We don't want to standardize one landing gear to the extent that we don't give anybody the opportunity of building a better one."

Another problem is that engineers working on computer terminals may find themselves mistaking computer simulations for reality. A story has been going around among engineers about a young designer at a British aircraft company, who created an igniter for a jet engine on the computer screen. Although it was a fine igniter, somewhere along the way a decimal point was moved one place. The computer therefore instructed a machine tool to cut out a part that was ten times too big. When the machine operator brought the part up to the designer, the designer didn't see anything wrong.

Like many hourly workers in automated factories, engineers working downstream will have less autonomy yet faster-paced work. "Some computer-aided design systems we have looked at increase the decision-making rate by 1,800 or 1,900 percent," says Mike Cooley, a former senior design engineer at Lucas Aerospace and now with the Greater London Enterprise Board. As the engineers try to handle data at that pace, making low-level judgments yet being overseen by superiors upstream, says Cooley, "the stress is enormous."

Technological Control or Humane Work?

The managerial obsession with technology as a way to establish tighter control over production became an overriding theme in our study of automation. Managers often find it hard to exert close control over a skilled worker such as a machinist, who is making many intricate cuts to produce a complex part. The task is so difficult that a manager must simply rely on the machinist to work at a reasonable pace and to produce a good part. Skilled workers also have substantial bargaining power: if they walk off the job, untrained hands cannot fill in. Thus, managers intent on control seek to remove skill from workers and transfer it to complex machinery. The resulting jobs are tedious, high-paced, and stressful.

Moreover, there are hidden costs to this path. Observers of industrial management widely agree that workers are more productive and do a better job if they are motivated and able to use their skill, experience, and creativity. These abilities are especially important in the case of computer-based technologies, which—in reality if not in theory—depend intimately upon workers for smooth functioning.

Under certain circumstances, managers can increase output while making work more routine and stressful. However, concern for improving production should not outweigh consideration for what workers do on the job. Degrading the work people do ultimately demeans their lives—a cost that is seldom figured into calculations as to which system is more efficient. Computer-based automation holds extraordinary promise for improving life on the job. The emphasis should be on realizing that promise.

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Negotiating the Factory of the Future

BY JONATHAN SCHLEFER

To judge by official pronouncements last spring and summer, the entire city of Lynn, Mass., was euphoric about General Electric's proposal to build what everybody called a "factory of the future." Mayor Antonio J. Marino proclaimed the facility "the greatest thing that ever happened." John Murphy, business agent for Local 201 of the International Union of Electrical Workers (IUE), said, "We can sit at our anvil with our copper hammer or enter the twenty-first century." The Lynn *Daily Evening Item* editorialized: "What is good for General Electric is good for Lynn."

The factory of the future sounded like such a wonderful idea that one might have wondered why everybody was making such a clamor to prove it. But despite the euphoria, a contest did seem to be shaping up pitting the solid citizens of Lynn against a whispering gallery of naysayers.

Al DiVirgilio, president of the city council, lambasted a "demagoguery element of the union" that questioned GE's proposal, though he failed to name the demagogues or explain their questions. In an article in the *Item* entitled "GE: Make Lynn a Showplace for America," reporter Tom Dalton noted "a few signs of disenchantment within the union" about the proposed factory. He did not explain the criticisms, but quoted a union official as saying they were promoted by individuals who didn't know "schlock from shinola."

Mystery Factory

One thing everybody knew was that GE wanted special work rules for the factory of the future. Although the company had mentioned earlier that the plant might be built, Local 201 first heard about the work rules on May 7, and GE said union negotiators would have to agree to a contract embodying them by June 8. If union members voted the contract down, as a company flier put it, "the $50 million plant will be built at some other location," such as Hooksett, N.H., a non-union GE facility. The fear of just that haunted the old industrial town of Lynn.

The thing almost nobody could tell was what the new plant would be like. As James N. Krebs, general manager of the GE operation that was building it, said, "Union members don't know the details of the plant. All they know is that it's automated." The *Item* hardly cleared much up by saying the factory would contain "robotics—or robot-like equipment."

A word of background may be helpful. GE's Aircraft Engine Business Group built the first U.S. jet engine in Lynn in 1942. Today the division supplies engines for aircraft from Boeing 747s to commuter turboprops, from the air force's B-1 bomber to its F-16 fighter. The jet-engine business is one in which the United States is still a leader, and Krebs intends to keep it that way. "If we could beat our competitors on cost *and* performance," he said, "that's the way to assure our future." The factory of the future, he believed, would keep costs down.

Sometimes GE engineers used a more modest term for the plant, calling it a "flexible machining center." Plans called for the FMC to have about 25 lathes and a few other machine tools to cut jet-engine parts to accuracies of 0.001 inch. Robots would

Union members could vote for or against the factory of the future, but they didn't know what shape it would assume.

load workpieces onto and unload them from the computerized machine tools. A "host" computer would direct the entire plant, devising production schedules, maintaining inventories, and tracking costs.

On each shift two or three electronics-repair workers and five or six mechanical-repair workers would keep the complex technology functioning. In addition, 17 or 18 "stagers" would mount raw workpieces precisely in fixtures to hold them as they were carried through the FMC, and would mount cutting tools equally precisely in cartridges to be used on the machine tools. The stagers would also attend to a number of other jobs such as "benching"—cleaning off rough burrs from machined parts, a task at which automated machinery does not excel. In a control room overlooking the factory floor, ten managers and engineers would supervise the operation.

The FMC would be only one of many plants at GE-Lynn, and in most of these automation has its limits. For example, the thousands of parts that make up a jet engine are carefully assembled and adjusted by what one can only call craftworkers. They exhibit a care and pride that could be compared to that of the makers of Haynes flutes.

As for the FMC, even management couldn't be sure how it would work. Local 201's Murphy visited an FMC that produces frames for locomotive engines at GE's plant in Erie, Pa., and said, "I expected to see some big shining star out there. I couldn't believe how dirty the place was." The conveyor system to carry away the metal "chips" cut from workpieces had problems. "And there was one guy with a big copper sledgehammer beating the parts. I asked the manager if this was the way the job was supposed to be done. He said, 'We're having a little bit of a problem.' The parts were supposed to be fitted together, but the automated equipment was somehow malfunctioning, so the worker was just pounding them."

Three Demands

Press coverage of the three points GE had insisted on incorporating into the new union contract was so scanty that few could have understood them. The point that did receive attention, perhaps because people could discuss it without knowing about the technology, was the "12-hour workday." When the FMC went into full operation in 1988, workers would put in three 12-hour shifts one week followed by four the next, for an average of 42 hours. They would receive normal wages for the first 8 hours each day and time and a half for the

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NEGOTIATING THE FACTORY

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next 4. This would mean a minimum of $2650 in additional wages each year.

A 12-hour shift makes some sense if management wants to run a plant 24 hours a day for 7 days. Trying to use work weeks of five 8-hour shifts can cause problems, with individuals working constantly changing schedules. GE management maintained that it was just trying to do something enlightened.

Ron Malloy, vice-president of Local 201 and a critic of GE's proposal, wasn't convinced. He considered the 18-minute lunch during the first 8 hours and the 12-minute break during the next 4 hours stingy. Critics also objected to the company's plan to lengthen the work week while increasing automation.

However, the 12-hour workday was a selling point to many union members, and even critics say it was the least of their concerns. The irony was that the minor issue received so much attention: it was the only one covered in the *Boston Globe*'s two articles on the factory.

As the *Item* mentioned only in passing, the second point GE wanted was "day work with measurements": the company would establish "reasonable and attainable measurements" as to how much workers should accomplish in a shift. The national IUE contract already gives GE the right to direct the workforce, and the company has always required workers to fill out vouchers showing how much they accomplish. However, Malloy said that no contract had specifically granted the company the right to measure the output of day work-

ers. (Pieceworkers, paid by the number of pieces they produce, are a different case.) The company could fire a worker only for "just cause," not for failing to meet a quota, Malloy said. "Now the only thing we will be able to arbitrate is whether the measurements are attainable. You can get any whirlwind to do a job. Is that attainable? Well, he attained it."

If GE secured a measured-day-work agreement from Local 201, which has the reputation of being militant, the company would try to do the same with other locals and incorporate it into the national contract, Malloy believed. Frank Emspack, a member of the union's executive board, added, "I think the point is to marry measured day work to computer-based monitoring systems and hold day workers to increasingly high levels of production."

Krebs does want to increase productivity 10 percent a year, even in existing facilities, and believes that computerized management systems can help to achieve this. "In plants where we've got computerized vouchers," he explained, "we're able to confront the front-line manager and say, 'Look at the record of your workers.' The manager can confront the person and say, 'This is subpar.' Or, 'Why is this machine down all the time?' And the person may say, 'Well, it's a dog.' Or he may say, 'Yesterday I stood in line three hours for tools.' You find out all kinds of things—sometimes you're not doing your management job well enough.

Finally, GE wanted to substitute a few broad job classifications in the new plant for dozens that now exist in its factories. Initially the *Item* reported that the jobs were "relatively low-skilled." As the union vote approached, those same jobs metamorphosed, without explanation, into "only skilled and high-skilled positions"—the company position.

GE in fact proposed that the electronics-repair workers be R-25—the highest rate, or skill level, at any GE plant—and that the mechanical-repair workers be R-23. Critics saw no problem there. But they objected strenuously to GE's proposal that stagers who would feed workpieces into the FMC and put tools in cartridges should be R-17.

Most of the metal-cutting machines in the FMC would be lathes, and the basic rate for a lathe operator has always been R-19. When GE-Lynn introduced automated lathes in the early sixties, it tried to cut the operators' rate to R-17, while increasing the workpace, according to David F. Noble, curator of industrial automation at the Smithsonian Institution. Angered operators reduced their output, and GE secretly restored a few to R-19, hoping that they would informally break the slowdown. But the operators got wind of what was going on and walked off the job on October 6, 1964. After continued wrangling and a month-long strike, the R-19 rate was restored.

A lathe operator is a lathe operator, whether in a conventional shop or a factory of the future, according to union members. They did not particularly buy GE's contention that the "average" rate, counting the R-25s, R-23s, and R-17s, would remain unchanged in the new plant. "R-17 is semiskilled," said Emspack. "The heart of the rate structure of a machine shop is the R-19 machinist. If you undermine that rate, you have ruined the structure."

Murphy said that the union might well press for R-19 or even R-20 after the new plant was built. If GE's managers were unreasonable in setting skill rates or the workpace, he said that he would start a grievance procedure, and he emphasized that the agreement did not give up the right to strike: "If their whole plan is to play games with us, when they get that $50 million plant across the street, they'll find out that it's really a game they will regret."

But at the time, the union's bargaining leverage was limited. Krebs not only held up the threat to build the FMC elswhere. He also suggested that GE might well invest an additional $450 million in the Lynn facilities over the next five years, but that a no vote on the FMC would hardly provide encouragement to do so. "If we told the company to take their $50 million and stick it," said Murphy, "there's no question that not only wouldn't we see the $450 million; we might actually wind up having some of the work that's now done in Lynn diverted someplace else."

Emspack observed that troubled companies have secured concessions from unions, but "GE had a new idea: how to get concessions if you are booming. You use investment. You are wealthy, but you could be more

If the union voted no, the $50 million plant would be built elsewhere.

wealthy if you invest in New Hampshire."

What Choice?

On June 26, the union members voted three to one for the factory of the future.

GE-Lynn had acted in many ways like an enlightened business. Krebs says superiors in GE had urged him to build in a non-union location, agreement or no agreement. Only those who choose to will be assigned to the new plant (about 100 union workers will be employed there). GE pledged its intent not to reduce the number of workers in the plants now making the parts that the FMC will produce. To back this up, the company will for the first time let union members discuss which work is to be contracted out and which done in-house. Given the duress they were under, union negotiators did well.

However, the imbalance of power tipped heavily against the union led to an unsatisfactory outcome. "Nobody said, by God, I've seen this thing, it is the way of the future, and I really like it," said Emspack. "The key point was fear. The company said investment decisions were involved. Well, hell, that's your job." Even Murphy admitted, "Everybody's scared of technology. I would rather stay with the status quo, but that's totally unrealistic."

The heart of the machine-shop structure, the R-19 machinist, may be headed for eventual extinction. And the measured day rate, together with computer monitoring, can hardly improve worklife. Given the skill and care of those who assemble engines—qualities that surely contribute to the U.S. lead in this industry—GE managers might consider whether their apparent increase in control through technology will be counterproductive in the end.

More fundamental is the failure of almost the entire city of Lynn to see technology as anything but an inexorable march toward a predestined outcome. "Make no mistake about it, technology is the future," editorialized the *Item*, not mentioning that different technologies might lead to different futures. Edward Hood, vice-chairman of GE, told Lynn workers, "You have been given an opportunity to prove you can accept new technology and become more productive."

Because the leaders of Lynn believed that technology proceeds along a predetermined path, they saw no need for the union to affect technological change. That is what dissident unionists refused to accept. Rather than being pressured to negotiate in a month's time, said Emspack, "I would like to have had a serious technical explanation of the FMC. We could have analyzed it. Does it have to be designed this way? How can we increase skills? Do we have to eliminate the eight-hour day? The take-it-or-leave-it attitude has nothing to do with the factory of the future. It has to do with labor relations of the past. Certainly, it is not innovative technology."

Corporate managers will continue to be the sole designers of technology until the public, the press, and politicians realize that technologies can be designed in different ways, and until power is more balanced between corporations and the workforce. In West Germany, for example, laws require worker participation in planning new technologies, and labor is routinely represented on corporate boards. For whatever such figures are worth, manufacturing productivity in West Germany has been increasing at twice the U.S. rate.

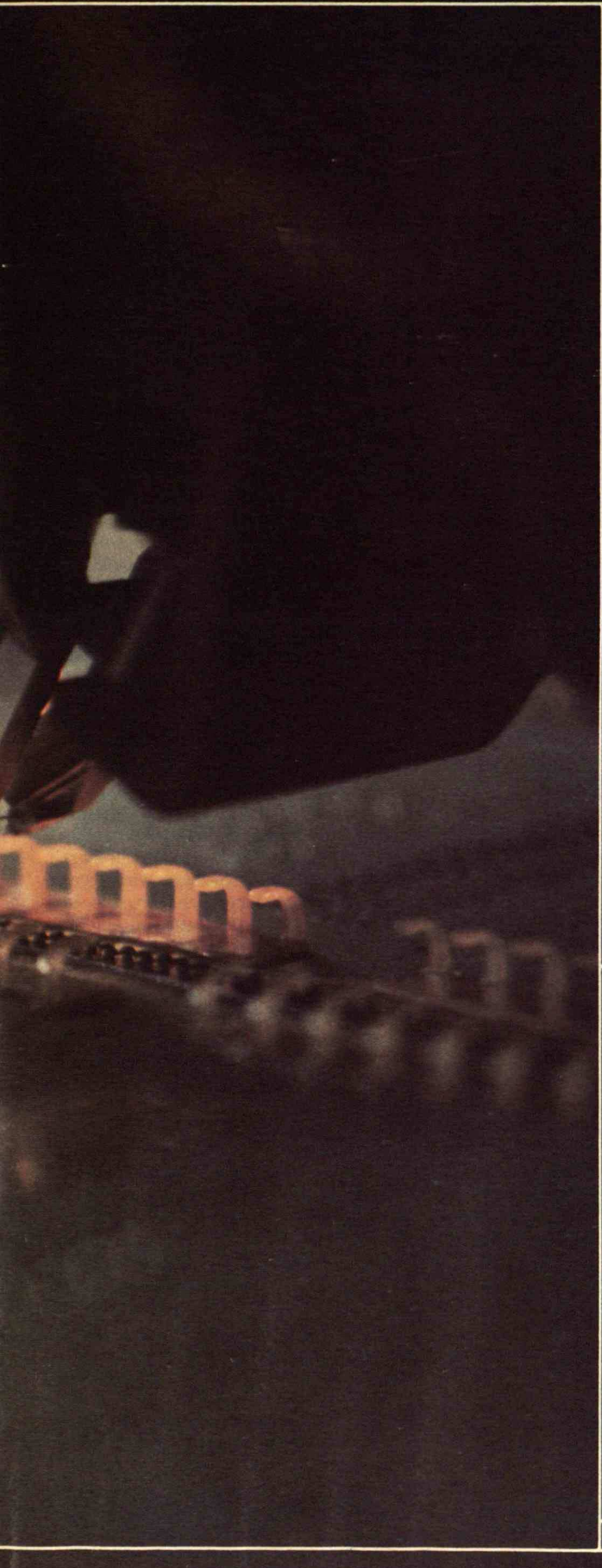
JONATHAN SCHLEFER is a senior editor of Technology Review.

A computer drives this wire bonder to the proper location to repair or change the configuration of a printed circuit board.

The Automated Factory: Vision and Reality

BY MARJORY BLUMENTHAL AND JIM DRAY

Paying attention to the way factories really work, instead of indiscriminately embracing computer technology, is key to a strong manufacturing sector.



ADVOCATES of automation often paint a utopian vision of a factory run almost completely by computers. Machining centers hew metal, robots transport workpieces, and finished parts are placed in storage automatically, their whereabouts duly noted in the computer's memory. Proponents argue that such factories will make U.S. manufacturing competitive.

This view is, in the end, simplistic and misleading. Manufacturing operations may seem simple—until you try to reduce them to computer programs. Then cleaning up metal shavings, aligning odd-shaped parts, and routing work around broken equipment do not turn out to be so easy. Automating many tasks may

PHOTOGRAPH: IBM

not be technically or economically practical.

The common bond among successful manufacturers, we found while conducting a study for the congressional Office of Technology Assessment (OTA), is not a preoccupation with autonomous machinery, but close attention to the way products are actually manufactured. Many managers find that the key to refining the competitive edge is clever product design, a streamlined flow of parts and materials through a factory, or better relations with customers and employees.

Of course, we do not mean to imply that manufacturers can ignore automation. Some find that it alone boosts productivity, and surely all must seek ways to tap its enormous potential. We will examine both the promises and the limitations of the principal manufacturing automation technologies, and will suggest how they can be used most effectively.

Using Computers in Design

Computers are potentially useful throughout manufacturing—in designing products, storing and retrieving inventories, making and assembling parts, and, of course, managing the entire enterprise. The logical place to start is computer-aided design (CAD). In the late fifties, as Sylvan Herbert Chasen of Lockheed-Georgia recalled in *Mechanical Engineering*, "the ability of the computer to spill out reams of geometric data had outpaced our ability to cope with it." Researchers therefore began exploring the use of the computer screen to display and manipulate shapes. The next logical step was to use such computer graphics in engineering design. SKETCHPAD, developed in 1963 at M.I.T. with funds from the Department of Defense, was a milestone in CAD development. Operators could draw pictures on the screen and alter them with a light pen—a pen-shaped object wired to the computer.

Early CAD systems required the largest computers of the day and were primarily used by aerospace, automotive, and electronics manufacturers. However, as with all computer-based technologies, costs have plummeted. By the end of 1983 some 32,000 CAD workstations were reportedly in use in this country. Custom systems based on mainframes cost millions of dollars, but minicomputer-based "turnkey" systems, intended to be ready for use, cost around $500,000. Microcomputer-based systems sell for under $100,000—some for as little as $10,000.

Thinking of robots anthropomorphically may lead to inefficient applications.

Though most CAD systems have keyboards, more useful devices for entering information include a light pen, a touch-sensitive drawing board known as a graphics tablet, and a "mouse," which is moved on a nearby surface to control a pointer on the screen. A digitizer can read the contours of any drawing or model into the computer.

Because designs are stored on a computer disk, operators can recall and revise any that have been done on the system, and they often have access to a library of stored shapes. Operators can reproduce part of an image and move it, zoom in on a small piece and change its size, and rotate the design to view it from different perspectives.

Most systems create two-dimensional drawings; this is all designers need for many products such as electronic circuits. Some systems, largely set up to design complex mechanical parts, can produce images that appear three-dimensional. They often look like wireframe models; however, the most advanced "solid modelers" produce realistic images of parts and can actually be used to analyze a part's performance. For output, CAD systems have plotters to make precise and often multicolored drawings, and some can produce microfilm or microfiche copies.

Estimates vary as to how much time CAD saves. Those who use it typically claim that some tasks can be performed two to six times faster than by manual design methods, although such estimates tend to ignore the "set up" time that the computer usually requires. Engineers at the Prototype and Plastic Mold Corp. in Middletown, Conn., for example, say they can design metal molds for plastic parts about twice as fast with CAD as previously. They cite an instance in which they received specifications for a plastic part one Saturday morning and produced the drawings for a mold by evening. This would have been impossible without CAD.

CAD is particularly useful for products with repetitive features. For example, in designing the new 757 and 767 Boeing aircraft, engineers used CAD to minimize redrafting of families of parts such as wing ribs. CAD may also help improve products by allowing designers to "try out" a dozen or even a hundred variations, where previously they might have built only a few prototypes. However, CAD can be cumbersome for the inexperienced, and even seasoned operators may find unusual shapes easier to draw with a pencil.

Advanced CAD systems go beyond electronic drafting in two ways. In what some call computer-aided design/computer-aided manufacturing (CAD/CAM), engineers use CAD to generate the computerized instructions for manufacturing equipment. For example, at Boeing, CAD/CAM makes it easy to produce a custom interior for each airplane: after the designer draws a plan, the system generates instructions for manufacturing equipment to drill and construct the needed panels.

CAD/CAM has been widely publicized and does promise extraordinary shortcuts. But so far, interfaces between CAD terminals and computer-controlled machine tools have proved relatively cumbersome and inflexible. According to experts consulted by OTA, sophisticated CAD systems connected directly to manufacturing equipment will not be commercially available until the late 1980s, and they will not be easy to purchase and use until the 1990s.

CAD can also go beyond electronic drafting to provide computer-aided engineering (CAE), which allows operators to analyze their designs. For example, CAE can check electronic circuits for potential faults. Designers at IBM's Poughkeepsie plant use advanced solid-modeling CAD systems to visualize computer cabinets, and can even "pull out drawers" in the image to be sure they do not hit cables. However, this system requires a lot of computing power, and generating an image of a cabinet from a new angle may take several minutes. Engineers can also use CAE to determine the stress on mechanical parts so they can be made light yet strong—an important feature in the automotive and aerospace industries where weight is critical. However, this use of CAE is far from common in other

PHOTOGRAPHIC RESEARCH: BIRGITTA MÅNSSON

industries. Experts consulted by OTA estimate that truly comprehensive and flexible CAE systems will not be developed, even in laboratories, before the late 1980s.

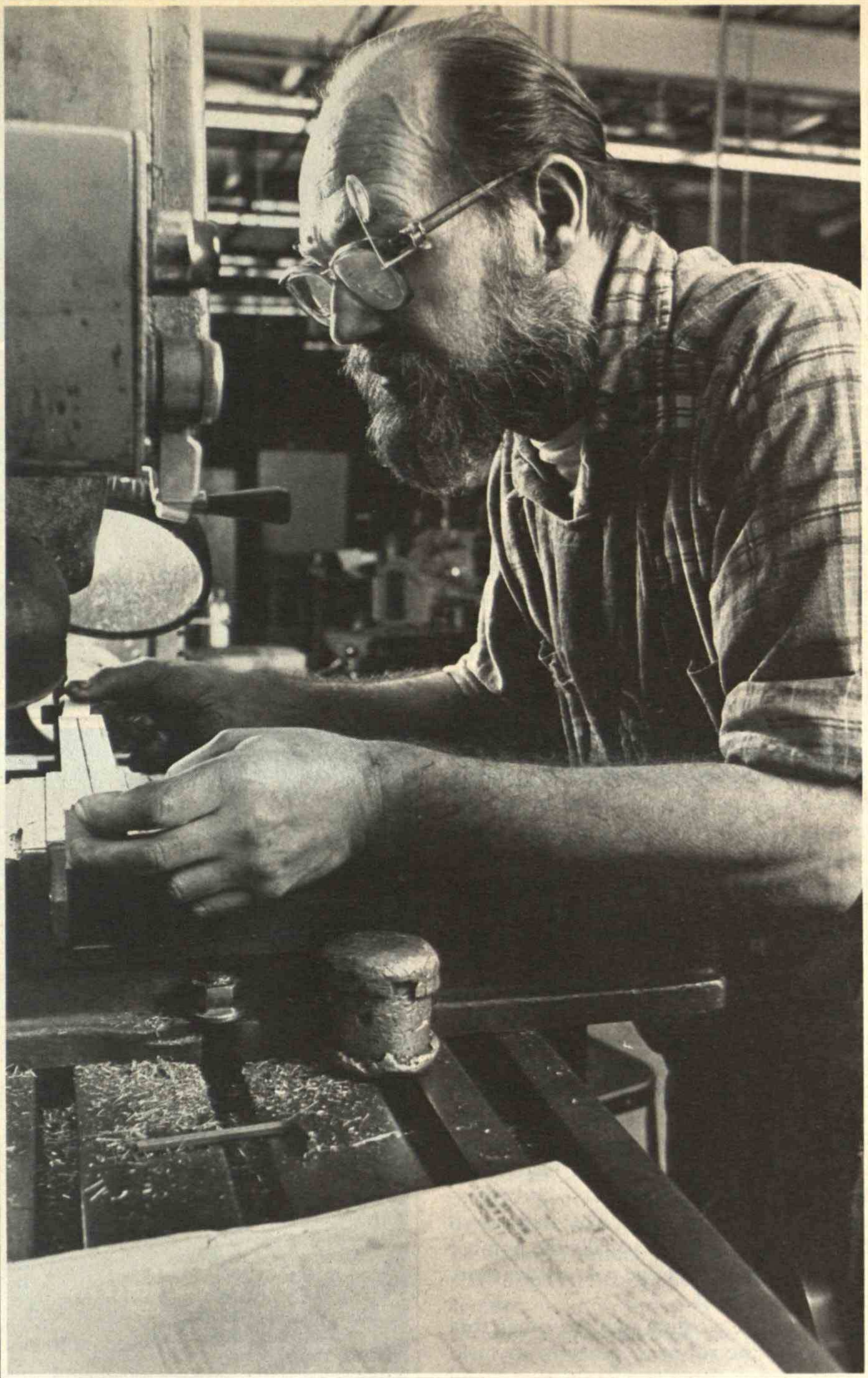
On the Factory Floor

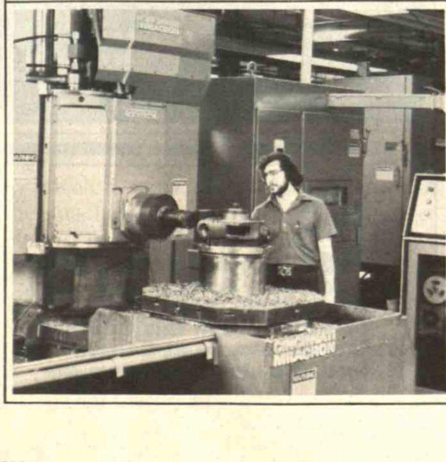
Automation is nothing new in factories. Detroit has long employed specially built automatic machinery that can, for example, bore cylinder holes in the block of a particular model of engine. However, with such hard automation, a design change requires expensive mechanical retooling.

What is new since the fifties is *programmable* automation—general-purpose machines that follow instructions, usually from computers, to perform specific tasks. Merely change the instructions, and machine tools cut a different shape, robots spray paint a different type of panel, and carts move inventories to a different location. The use of programmable automation to control machinery on the factory floor, called computer-aided manufacturing (CAM), is increasing, though only beginning to catch up with the use of computers in design.

Traditionally, manufacturers have based their decisions about the most appropriate level of automation for a process on production volume. Mass production of many thousands of products at a time typically justifies single-purpose hard-automation tools. Custom production of just a few products generally involves direct human guidance. In between, a vast array of manufacturing processes produces medium-sized batches of several dozen to several hundred parts. By some estimates, batch production accounts for 75 percent of all parts produced. For example, tractors, airplanes, marine engines, and much industrial machinery are made in varying batch quantities. Manufacturing on this intermediate scale does not justify hard automation; programmable automation is particularly useful because it enables a given set of equipment to produce a variety of goods.

However, there are exceptions to this rule. Even large-scale manufacturing is evolving toward greater product differentiation, making batch sizes smaller and the flexibility of programmable automation more attractive. And in custom production, complex parts can sometimes be cut with greater accuracy by a computer-controlled machine tool than one controlled manually.





A machinist (top) plans cutting procedures and shapes a part on a conventional machine tool. Bottom: On computer-controlled machine tools, operators rarely plan the cutting procedures. However, most managers agree that operators must still have some skill to set the machines up, make numerous adjustments, and ensure that nothing goes wrong.

PHOTOGRAPHS: STUART ROSNER; CINCINNATI MILACRON

Practical Robots

The enduring vision (or nightmare) of intelligent androids usurping the role of humans has no doubt sparked much of the popular interest in robots. After all, they made their debut in Karel Capek's 1923 play *R.U.R. (Rossum's Universal Robots): A Fantastic Melodrama*, and dictionaries continue to define them as "humanlike."

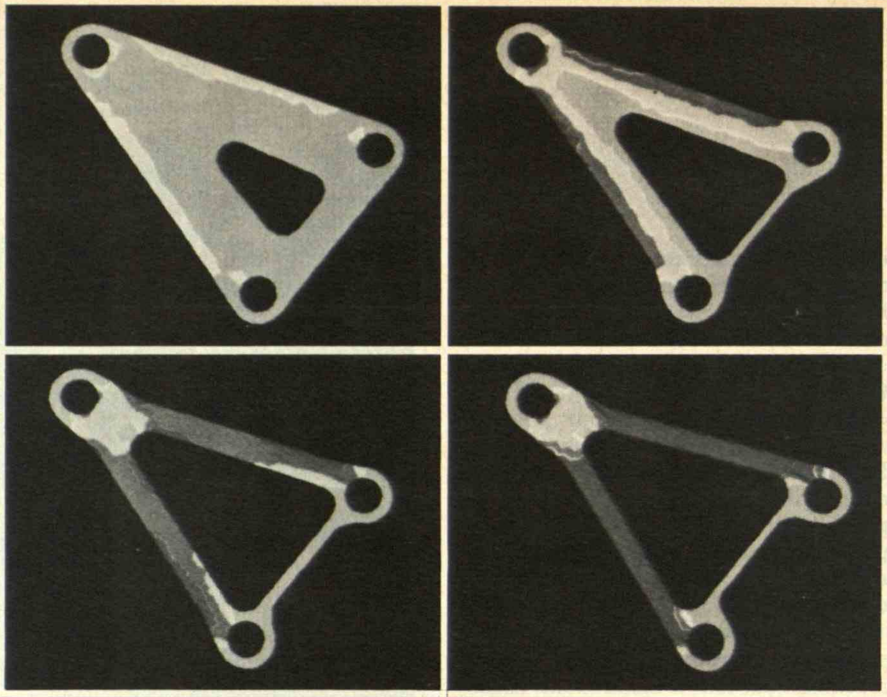
It is not clear how far artificial intelligence will eventually extend the capabilities of computers, but for the time being industrial robots are very limited compared with human workers. Robots have only a small fraction of a human's dexterity and ability to sense the environment—and essentially no judgment. In fact, thinking of robots anthropomorphically may lead to inefficient applications. As Warren P. Seering of M.I.T. has noted, today's robots often tighten bolts in half-revolutions like those a human wrist would perform, yet it would be easier and more efficient for the end of a robot's arm to revolve continually. A better, though more mundane, term for today's robots is "programmable manipulators."

Industrial robots have three main parts:

☐ The manipulator is the main body of the robot. Its base is usually bolted to the floor, although a few robots can move on tracks and others are mounted gantry-style—hanging from overhead supports. The mechanism that moves the arm may be hydraulic on many of the heavier robots, electric on lighter ones, and pneumatic on simpler units. The degrees of freedom of the arm—basically the number of joints—determine the robot's dexterity as well as its cost.

☐ A gripper, welding gun, or other tool is used by the robot to perform its task. Grippers are usually custom-made and vary greatly. Some can lift several objects at once, while others can grasp a fragile object without damaging it.

☐ The controller is the computer and program that guide the robot. There are two ways to program, the more common being teaching by guiding. As a worker moves the arm physically or via switches on a control panel, the controller records the path. This method is effective for tasks such as recording the curved motions needed to produce an even coat of spray paint. However, a path is hard to edit, or modify, without completely re-recording the task. The alternative—off-line programming, in which an operator writes a



Some computer-aided design (CAD) systems are more than simply electronic drafting boards. Top: In this CAD system developed at General Motors, the shading shows the stress a part will undergo, allowing the designer to make it light yet strong. Bottom: The operation of a robot is being planned on a video screen with this CAD system.

GENERAL MOTORS; COMPUTERVISION CORP.

program at a terminal to direct the robot—is just emerging. Off-line programs can be prepared while production continues, and computers eventually will be able to generate off-line programs automatically. Off-line programs can also give robots directions that depend on the situation, such as "if no part is present, wait for the next cycle."

So far, however, the vast majority of robots cannot sense the environment. The simplest sensors note whether a part is present: a detector mounted beside a conveyor belt recognizes when a part interrupts a light beam. More complex sensors, much like the one in the Polaroid SX-70 cameras, bounce sound off objects to estimate how far away they are. Such sensors may be used to stop a robot if anyone enters its work area, for example. Other moderately complex sensors can measure force in a robot arm to allow the gripper to apply just enough pressure to lift a delicate object.

Sensors that interpret visual or tactile information are just emerging. The Octek Corp. in Burlington, Mass., has a system that lights the edges of cups to count them. In general, though, the complexity of the everyday manufacturing environment, and the difference between a two-dimensional camera image and the three-dimensional world, make it extremely difficult for a computer to process a video image. It may well be easiest to organize manufacturing so as to avoid the need for complex sensors.

Simple "pick-and-place" robots with two or three degrees of freedom cost $5,000 to $30,000, while more complex models may run from $25,000 to $90,000 and up. Many of the first robots have been used for monotonous or dangerous jobs such as spray painting and spot welding, as well as for loading and unloading heavy parts. More sophisticated robots are now becoming practical for jobs such as assembling switches for appliances, sanding missile wings, and inspecting dimensions of parts.

The Robotic Industries Association (RIA), a trade group, estimates that by the end of 1982 Japan had some 32,000 robots in use, the United States 6,000, and West Germany 4,000. Though these statistics are plagued by some differences of definition, Japan clearly has more robots than any other country. This is partly because that country has devoted much effort to improving manufacturing technologies, but also partly because of its history of labor shortages. By contrast, the post-World War II baby boom resulted in labor surpluses for the United States during the late sixties and seventies, making it profitable for manufacturers to rely on labor rather than capital equipment. In any event, the number of robots does not determine the effectiveness of manufacturing processes. Overall manufacturing management has a far greater impact on productivity than the mere numbers of robots installed.

Manufacturing operations may seem simple—until you try to reduce them to computer programs.

Speeding Up Metalworking

On many factory floors, machine tools are the crux of the enterprise. On a lathe, the workpiece, or metal being shaped, spins and is cut by a stationary tool. On a drill or milling machine the workpiece is stationary while the cutting tool spins. Drills make holes; milling machines have many kinds of cutting tools that can be moved in numerous ways to produce a wide variety of shapes. A machining center is an automated machine tool that combines a number of functions. Simple parts are machined in a few minutes; complex ones such as ship propellers may take days.

Conventional machine tools may have motorized mechanisms to move the cutting tool and the workpiece, but the human operator controls the rate and direction of the movements. During the late forties and early fifties, the U.S. Air Force provided financing to M.I.T. researchers to develop a way to automate machine tools, known as numerical control (NC). The researchers used a computer to punch a paper tape, which in turn ran the machine tool, much like a player piano. The resulting NC machines were technically sophisticated and could shape intricate aerospace parts to precise tolerances. The computer language APT (automatically programmed tools) developed to control the NC machine tools was similarly sophisticated.

However, for most users outside the aerospace industry, NC technology went too far too fast. Even though several simplified versions of APT have been released in the last decade, some users say it still takes two years to train a programmer. Also, NC tools were and continue to be expensive. While a conventional machine tool costs $10,000 to $30,000, an NC machine costs $80,000 to $150,000 and up.

So for decades, many shops, particularly small ones, did not use NC machine tools at all. By 1968 only 0.5 percent of machine tools in metalworking industries were NC, and by 1978 the figure was still only 2 percent. Even by 1983, only 4.7 percent of the machine tools in metalworking industries were NC, according to the latest survey by *American Machinist*.

These statistics may underrate the increasing importance of numerical control for a widening range of industries. In a typical machine shop today, operators might have five NC machines running continuously to produce sizable batches, while machinists are at work on only a few of the 50 or so conventional tools, producing a relatively small number of parts. Each time a machinist using a manual machine wants to make a different cut, he or she must stop and make adjustments such as changing the cutting tool or reclamping the workpiece. Once an NC machine is programmed, it can perform a whole sequence of cuts, changing tools and reorienting the workpiece as required. Thus, up to half of all machined parts may be made by numerical control.

Though controlled by tape, NC tools still require human operators at least part of the time, and most managers agree that operators must be skilled to produce good parts. The operator's jobs include:

- ☐ Aligning the workpiece precisely in the fixture that holds it. A misaligned workpiece will be machined inaccurately.
- ☐ Listening to the cutting tool and replacing it when necessary—ideally before it fails.
- ☐ Removing the metal "chips" produced by the cutting tool.
- ☐ Adjusting "speeds and feeds"—the speed at which the cutting tool spins and the rate at which the workpiece is fed in. These adjustments depend on the hardness of a particular batch of metal and the sharpness of the cutting tool.
- ☐ Monitoring the quality and accuracy of the cut.

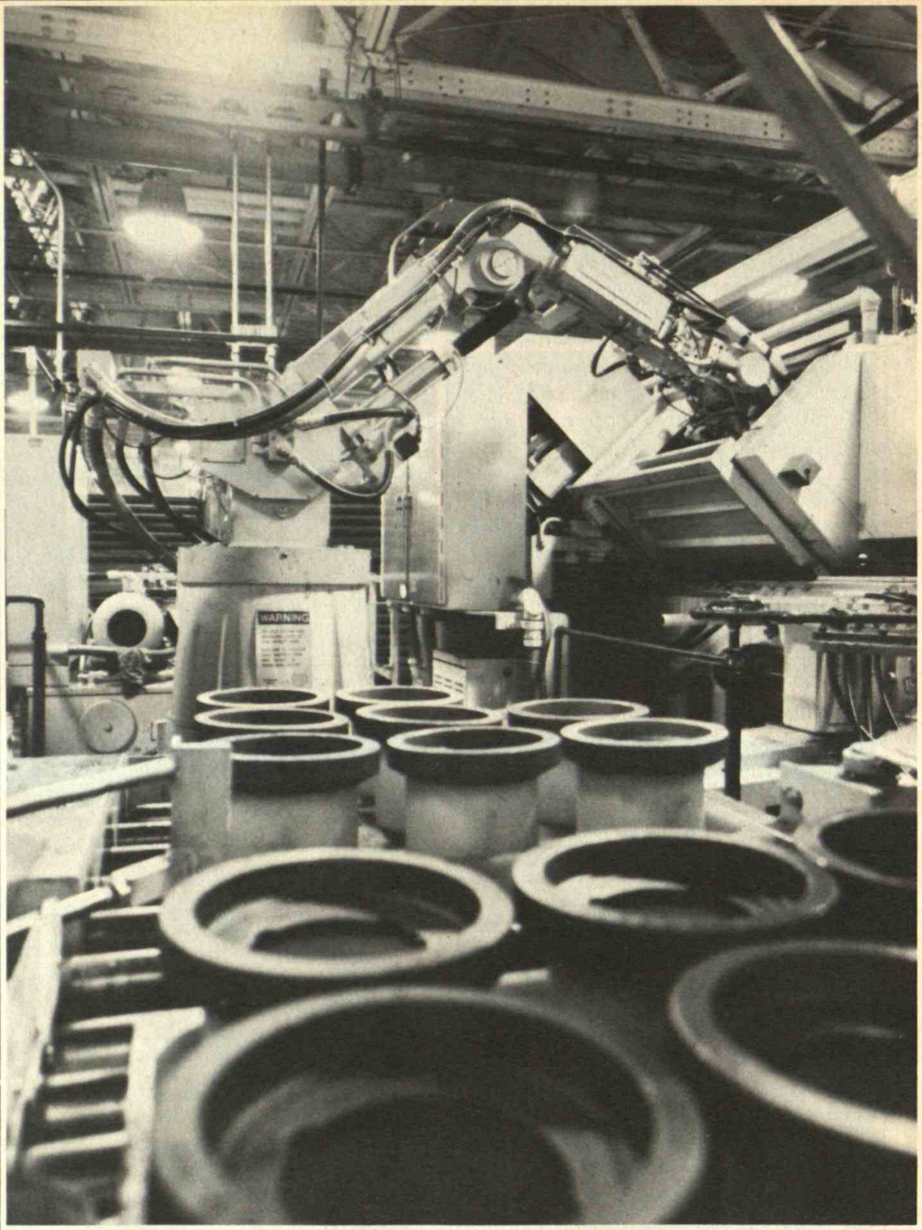
☐ Preventing accidents, such as a tool's cutting into a misplaced clamp.

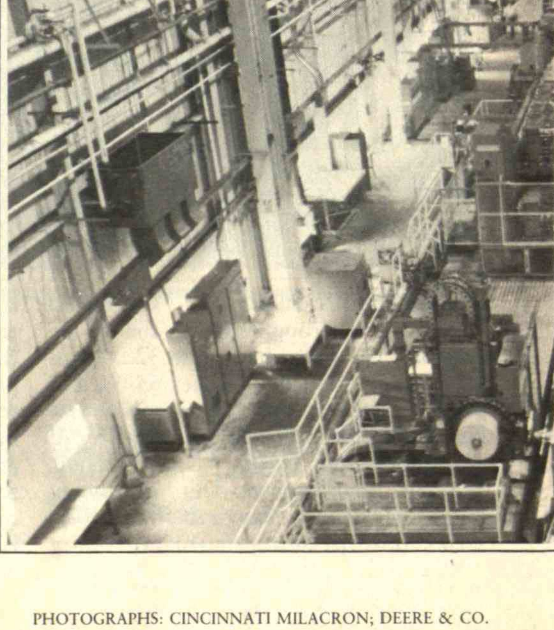
In general, the more complex the part, the more skills required of the operator. However, researchers are continually trying to automate many of the operator's tasks, etching away at the amount of time he or she must spend at a particular machine.

The programmer who produces the NC tape typically works in an office away from the factory floor. In fact, only a few programmers are experienced machinists. Programs often have mistakes—a misoriented tool can drill a hole in the wrong place or become chipped—and debugging takes anywhere from two hours to two weeks.

Since 1975 some computerized numerically controlled (CNC) machines have come equipped with their own minicomputers, screens, and keyboards for operators to write or edit programs. A related technology is direct numerical control (DNC), in which a central computer runs a number of machine tools.

Some manufacturers have designed NC tools to take over the machinist's job of optimizing cutting rates—that is, cutting metal as fast as possible without breaking tools. However, such attempts have so far met with limited success. Automatic sensors to detect wear in a broad range of cutting tools are only now being developed, and no reliable machines are available to remove a wide variety of chips. Thus, automation of machine tools still has a way to go.





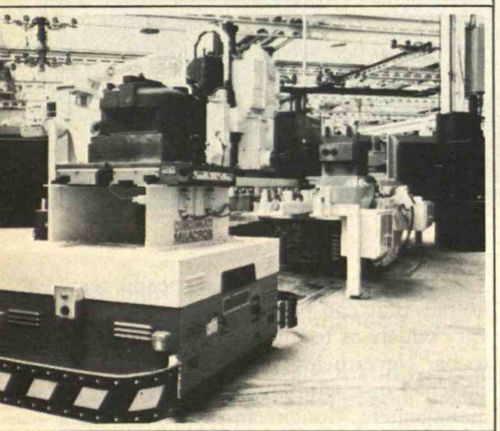
Individual pieces of automated equipment are increasingly integrated. The danger is that if a single component breaks, the whole plant may shut down.

Counterclockwise from top left: A robot loads a machine tool. Tank parts are automatically carried to machine tools to be shaped in this flexible manufacturing system (FMS). Materials-handling systems, such as this "robot cart," are crucial for integrating pieces of equipment but are also notoriously troublesome. A worker obtains information about an FMS that makes parts for agricultural machinery.

Putting Automation Together

The "factory of the future" referred to in the media is often actually a subsection of a factory known as a flexible manufacturing system (FMS). One that has received considerable attention is at a Fanuc, Ltd., factory in Japan that makes robots and CNC machine tools. This FMS is essentially an automated machine shop that produces parts for these products. When a machining center has finished with a part, a robot removes it and loads it onto an automatic vehicle. This in turn carries the part to another robot, which removes the part and loads it onto another machining center. Vehicles automatically store finished parts and retrieve raw workpieces. Only 19 workers are reportedly employed on the day shift to keep this complex machinery running, and the entire system operates at

PHOTOGRAPHS: CINCINNATI MILACRON; DEERE & CO.



night with only a supervisor in a control room. However, several other parts of the Fanuc factory, such as the section where parts are assembled into complete machines, are not automated.

An FMS may include not only machine tools but also other workstations such as inspection devices or heat-treating machines. Systems under development will have machines for grinding, sheet-metal work, and even assembly. Most FMSs have at least 4 workstations and some as many as 32. Moving workpieces from station to station may involve conveyors, monorails, carts on tracks, carriers that follow wires in the floor, or other automatic materials-handling devices. A computer controls the entire FMS, and its operation can be altered by programming changes.

A few FMSs are not very flexible and can produce, for example, only four different types of transmission housings. Other systems are being designed to make up to 500 different parts. Whatever the number, all parts belong to a common family. Round and rectangular shapes cannot be produced by the same FMS, nor can parts of unlike materials, such as common steel and titanium alloy steel. The parts' sizes and the precision required to make them must also be similar. FMSs are generally designed to produce small batches of any given part—usually fewer than 100.

Engineers develop a process plan—the sequence of production steps—for each part the FMS produces, often with the help of a computer. Based on inventory, orders, and computer simulations of how the system could run most effectively, managers establish a schedule every day. Operators feed each workpiece into the system, typically by clamping it precisely onto a fixture. The fixture holds the workpiece while it is being machined and also serves as a pallet while it is being transported. Once loaded with a workpiece, the FMS is essentially automatic. However, people must perform jobs such as repairing machines, replacing dull cutting tools, and cleaning up chips.

A properly working FMS provides many advantages. In a conventional machine shop, even one with NC tools, workpieces are often machined, allowed to wait, then machined again, allowed to wait again, and so on. An FMS makes manufacturing considerably faster, since parts move quickly and systematically from one workstation to the next. Thus, the manufacturer can reduce inventories of partially finished parts. Also, inventories of finished parts can be reduced since a small batch can be made to order. Reduction in inventories often provides one of the most significant cost savings of an FMS.

Messerschmitt-Bolkow-Blohm has achieved striking savings at its FMS in Augsburg, West Germany, that machines parts for the center section of Tornado fighter planes. M. Eugene Merchant of Metcut Research Associates in Cincinnati reports that the system keeps the machine tools cutting metal a spectacular 75 percent of the time. The FMS has roughly halved total production time and has also cut by half the number of machine tools and workers needed to do the job. Annual costs have been reduced by a quarter, and the manufacturer reports that even capital costs are lower than for an equivalent factory without an FMS. However, because of the complexity of the manufacturing processes, such figures are hard to ascertain, and one must take them with a grain of salt.

FMSs do have drawbacks. Robert Johoski of Cincinnati Milacron estimates that an FMS costs \$600,000 to \$800,000 per machining workstation, with a minimum expenditure of \$3 or \$4 million. Engineers planning the FMS must have considerable technical expertise and must spend one to three years preparing for the new system. Perhaps most important, the breakdown of a single component in an FMS can shut the whole system down because it is so highly integrated. Usually an FMS can reroute parts around a broken workstation, but the automatic materials-handling (AMH) systems are notoriously troublesome.

In fact, the materials-handling system may be the single most critical aspect of an FMS. One might think that moving parts from place to place, a task that workers generally do using wheeled carts, forklift trucks, or conveyors, is a mundane job. However, that perception itself is a problem: long neglected in industrial research, materials handling is in effect the glue that binds a factory together. Designing a materials-handling system that takes into account complex logistics, and that can place parts accurately and reliably on workstations, is no easy task. When humans handle materials, they make many apparently simple adjustments—such as not running into one another—that are more difficult for automated systems to accomplish. Often there is only one path, and when a

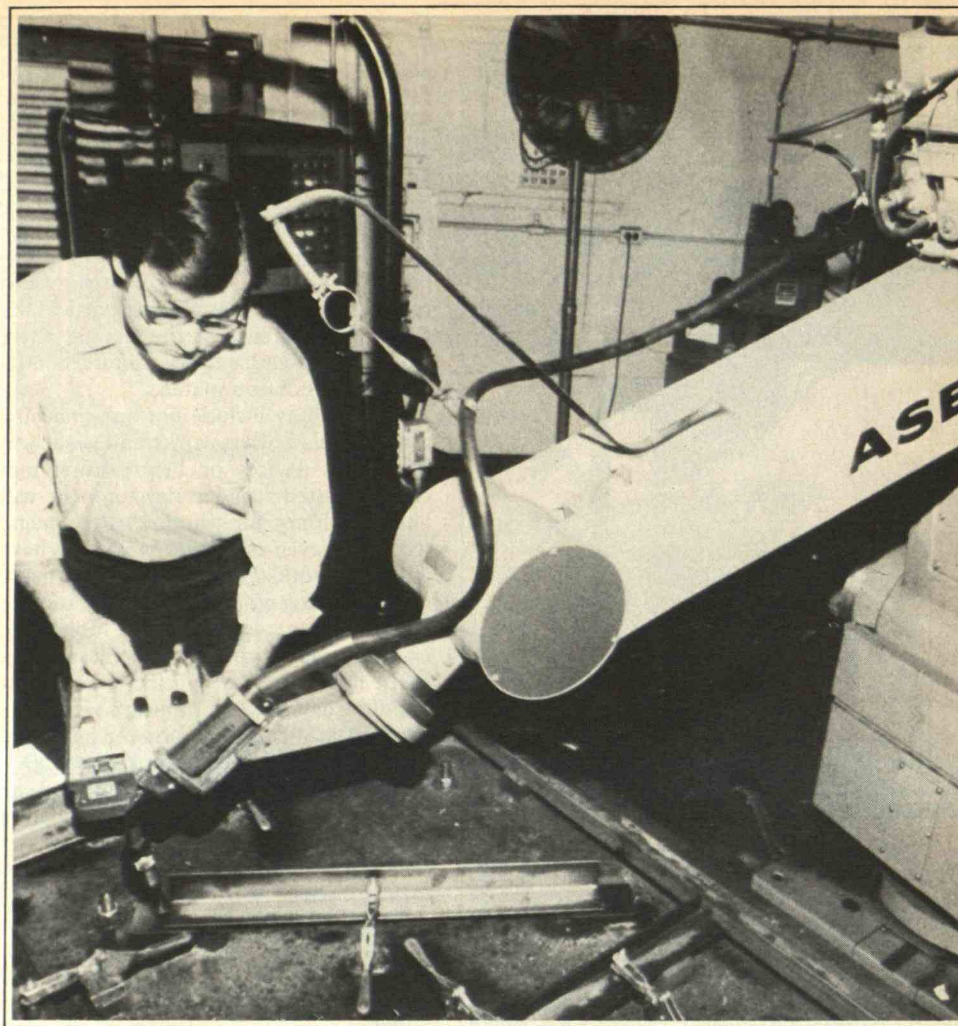
cart gets stuck, an entire FMS may stop. Designers have responded by including backup paths, or vehicles guided by wires in the floor that can be routed around obstacles.

Because of the difficulties of building and running an FMS, such systems are still rare. Reliable statistics are hard to obtain, but there are probably only 20 to 30 such systems in use in the United States, the same number in Japan, 20 in Western Europe, and another 20 in Eastern Europe. Still, interest in FMSs seems to have grown rapidly over the past couple of years.

Materials handling is also important outside the FMS. Some automatic systems transport work in progress from area to area in an entire factory. Because of the logistical difficulties in establishing paths for the AMH carriers, few such systems are in use. However, General Motors is reorganizing one of its plants and purchasing "robot carts"—ironically from Volvo—to carry automobiles throughout the plant, stopping at workstations for assembly. Volvo itself uses about 2,000 such carts.

Another use of AMH is for automatic storage and retrieval systems (AS/RS)—essentially automated warehousing. Computerized carts and lift trucks store parts in, and retrieve them from, tall racks. Automated storage and retrieval may require a smaller staff and keep more accurate inventory records than nonautomated storage, since every part is tracked by the computer. Deere & Co. uses an extensive automated storage and retrieval system at one of its tractor plants: workers can type commands into the computer for the system to retrieve parts from storage and carry them anywhere in the plant on overhead conveyors.

However, Deere's system also furnishes an example, described by Gordon H. Millar, vice-president for engineering, of how automatic storage and retrieval can go awry. At one point the computer was systematically reporting more engines on the racks than other records indicated could be there, and engineers searched for weeks to find the problem. It turned out that a roof leak was allowing water to drip past the photocell that counted engines as they were stored; each drip became an engine in the computer's inventory. Although Deere's specific experience may be uncommon, devising materials-handling systems may be one of the biggest problems facing engineers who would automate factories.



The Manufacturer of the Future

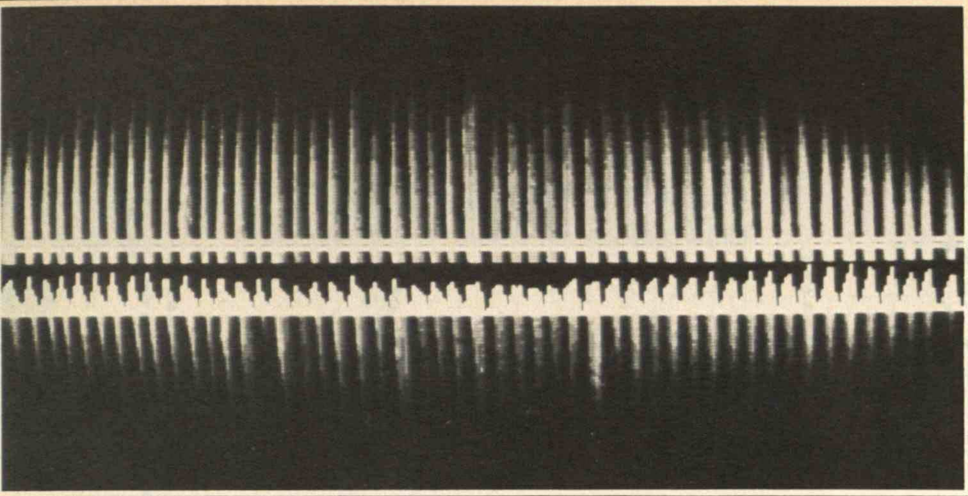
In addition to their direct uses in manufacturing, computers can serve broader managerial functions in organizing heretofore murky and chaotic manufacturing processes. First, computers can form the basis of management information systems (MIS) like those used in offices. These systems give top-level managers information about such things as orders, inventories, product designs, costs of raw materials, and the current status of production.

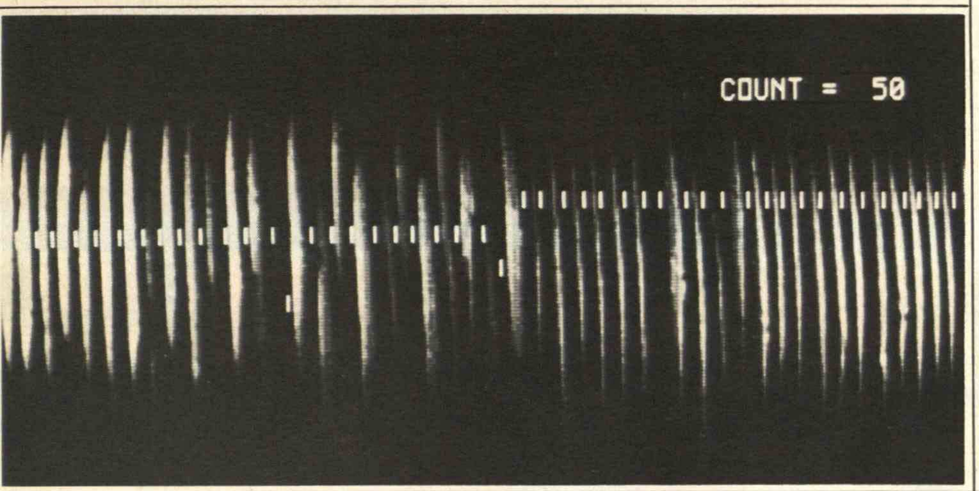
Computer-aided planning systems help managers schedule work. Manufacturing resources planning (MRP), perhaps the best-known such tool, is used to analyze orders, inventories, and work schedules to run factories efficiently. Computer-aided process planning (CAPP) helps to plan actual production steps on the factory floor.

The most ambitious goal in programmable automation is computer-integrated manufacturing (CIM, pronounced "sim"). An approach to coordinating computer-based management, design, and manufacturing systems, CIM has become a lightning rod for technologists seeking to increase productivity.

Actually, CIM is not yet a specific technology that can be purchased, and ideas vary widely as to just what it is supposed to be. Nevertheless, a sense of it can be sketched out. Computer systems used by management, design, and manufacturing would be able to communicate with one another. Design systems would be able to obtain data from management on the cost of raw materials and from manufacturing on how to adapt a design for efficient production. Manufacturing systems on the factory floor would use design data to plan the steps for making products. Management could use computers to acquire up-to-date information from both design and manufacturing databases to allow maximum coordination and centralized control.

James Lardner, vice-president of Deere & Co., sees today's advanced factories as a series of "islands of automation," in which machines perform tasks essentially automatically but connected by "human bridges." The ultimate step, in his view, is to replace the human bridges with machines and connect the islands into an integrated whole. In this essentially "unmanned factory," humans would per-





Welder Pete Bolger at Emhart Corp.'s United Shoe Manufacturing Plant (left) "teaches" a robot to weld a metal frame. Right: Designing manufacturing equipment that can sense its environment is difficult. This vision system developed by Octek Corp. of Burlington, Mass., lights the lips of cups (top) so it can count the total number (bottom). The unevenness of the image complicates even this simple application of machine vision.

form only creative tasks—primarily conceptual design. Many prominent experts echo this vision.

However, others argue that it is just a dream. "There is much talk about the totally automated factory," Barbara Burns, an engineering manager formerly at Lockheed-Georgia, has written. Although "these situations will develop in some cases . . . many manufacturing facilities will not be totally automated." Even those that are will require humans to design the manufacturing systems, as well as to control and maintain them, Burns believes.

Today management, design, and manufacturing databases still tend to be separate. Though many companies view their factories as examples of CIM, and a few such as Boeing and General Electric are making progress in implementing such a system, connections are almost invariably minimal, especially between CAD and CAM.

Making CIM practical on any broad scale would require not only technological advance but also a common format or language to allow automated components to communicate. Such standards will be slow in coming. Manufacturers argue that premature standardization will stifle innovation, freezing a technology at a particular point in its development. Also, present manufacturers sometimes fear that standardization will make it easier to combine different brands of programmable components and therefore will erode their market shares. Implementing any standard is voluntary in the United States and requires years of negotiation among manufacturers and users. To complicate matters, in the recent case of *The American Society of Mechanical Engineers v. Hydrolevel Corp.*, the U.S. Supreme Court held that a standard-setting organization may be liable for antitrust violations if a standard harms a particular company.

Finally, CIM faces resistance at many levels in industry. It is often said that the design engineer throws drawings over the wall to manufacturing—and there ends the relationship between the two domains. Echoing worries on the shop floor, middle managers often fear automation will diminish their authority or even eliminate their jobs. After all, it reduces layers of paperwork and allows top managers to get information about production directly. And as Robert H. Hayes and the late William J. Abernathy of Harvard Business School have pointed out, managers oriented toward short-run financial gains have often downplayed efforts to improve manufacturing processes.

It might be rash to claim that factories will never be run simply by managers and a few design personnel, but such factories are not in sight for the rest of this century. In the meantime, one of the biggest challenges on the road to the automated factory is taking into account the human factor. It is important to develop machines that people can work with effectively, and to identify the points where human responsiveness and creativity can contribute most.

MARJORY BLUMENTHAL was the director, and JIM DRAY a technology analyst, in a recent project by the Office of Technology Assessment to evaluate programmable automation. The report produced by the project, Computerized Manufacturing Automation: Employment, Education, and the Workplace, *is available for $14 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. A summary is available at no charge from Office of Technology Assessment, U.S. Congress, Washington, D.C., 20510.*

PHOTOGRAPHS: EMHART CORP; OCTEK CORP.

Science and Technology: The Driven and the Driver

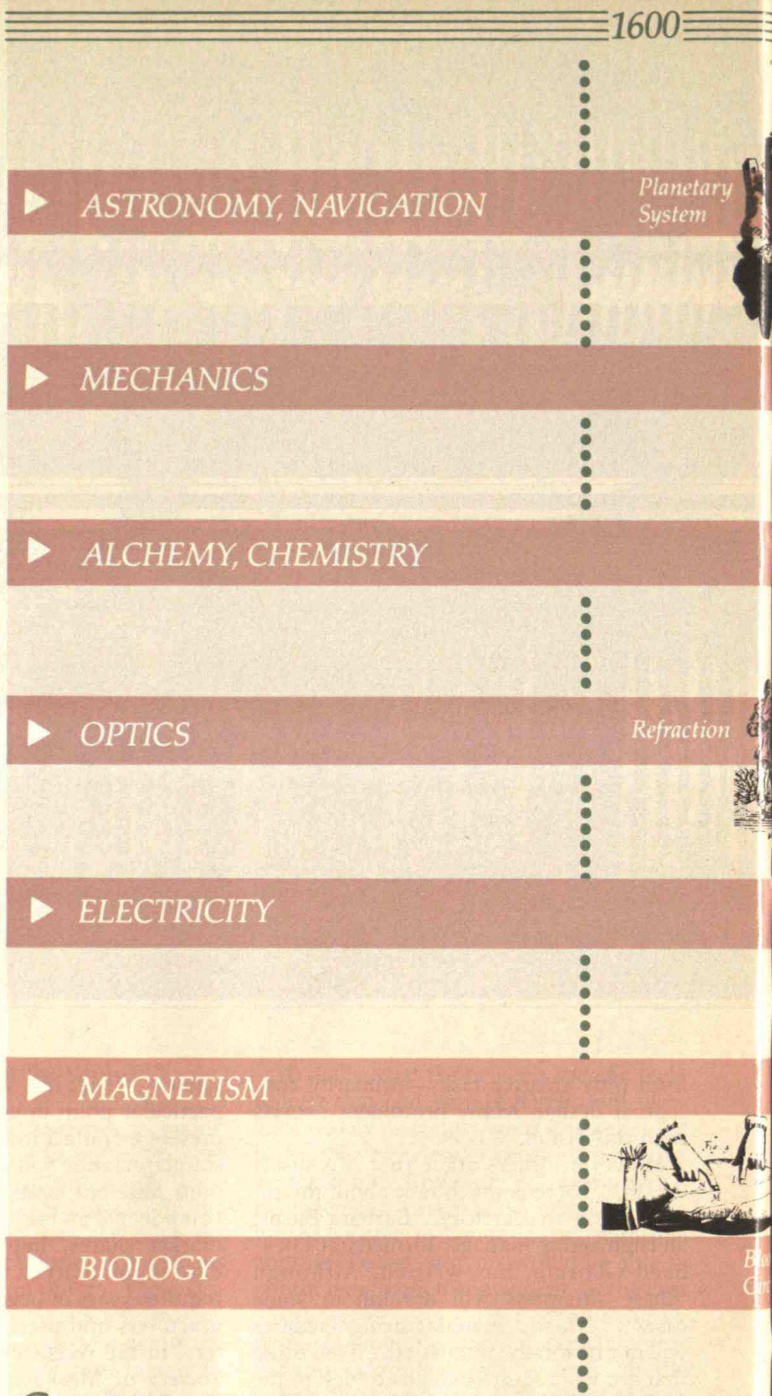
BY JOHN P. MC KELVEY

Science has traditionally been seen as a driving force for technology, but the inverse process is equally important.

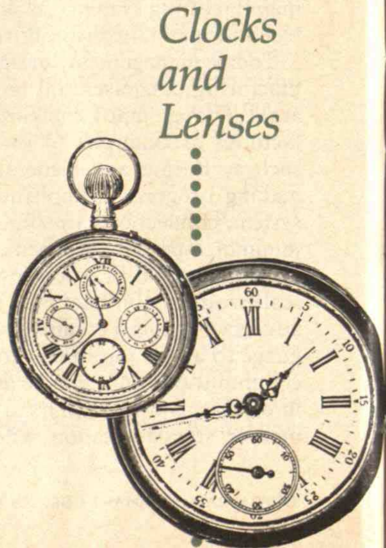
Have we now so organized our science and technology that maverick technologists cannot flourish?

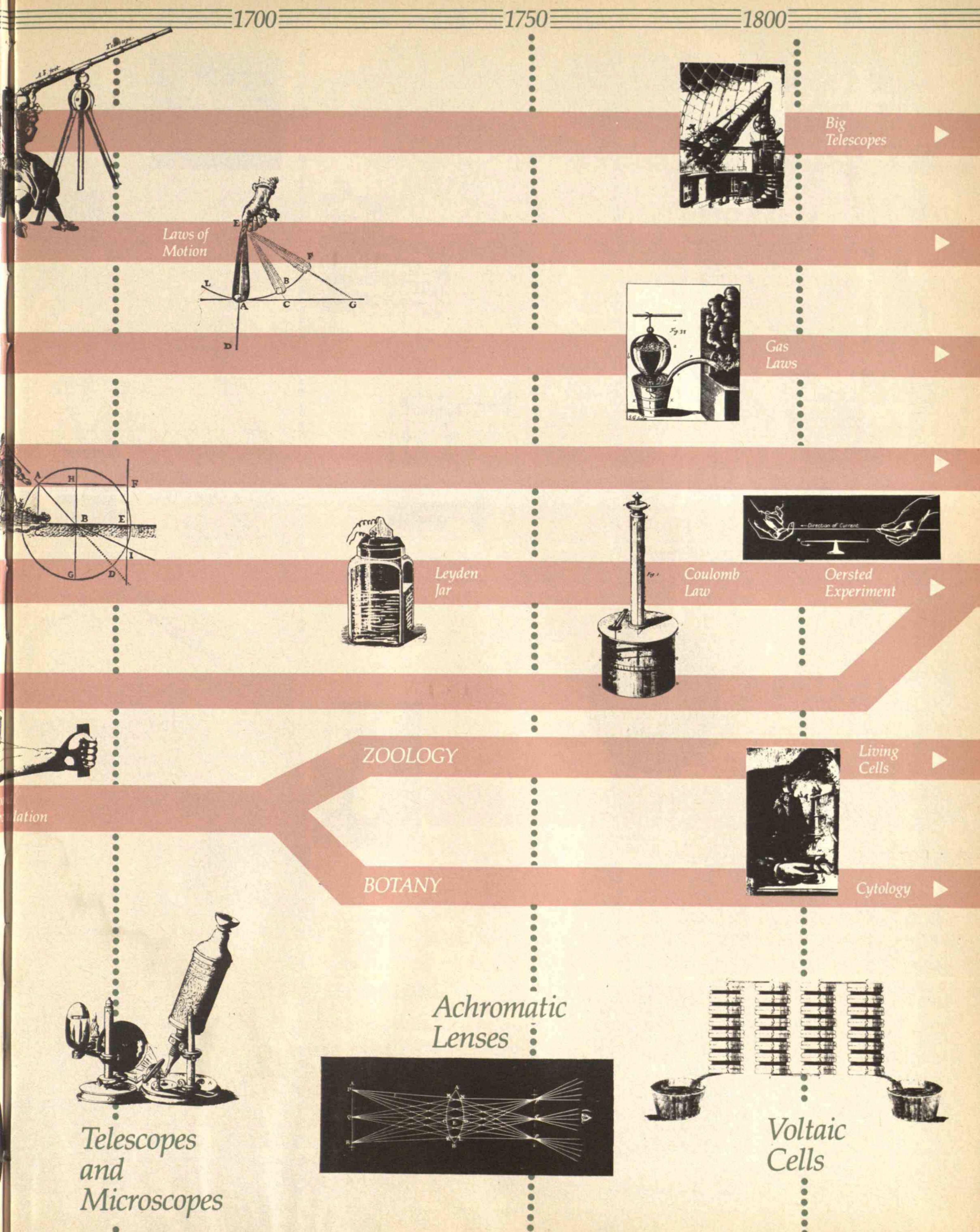
SCIENTISTS and engineers attend the same universities, sit in the same classrooms, and study the same textbooks. They even speak the same language—though in different versions, wherein different words are used to express the same ideas. But the interests and objectives of scientists and engineers are fundamentally different. Scientists are concerned with concepts, theories, and explanations, while technologists tend to emphasize tangible processes, products, and results. Engineers worry about costs, regulatory decisions, and patent protection, while scientists are interested in theories, experiments and predictions.

Like most generalizations, these have exceptions. But like the assertion that most Americans are either Republicans or Democrats, this suggested difference



Conventional wisdom says that technology applies scientific discovery to the service of humanity. But technology has made essential contributions to scientific progress. An example is the development of voltaic cells—now called batteries—which made possible studies of electric currents and electromagnetism. Alessandro Volta had no idea of the scientific principles that he invoked in building the first practical battery. This chart shows some of the many technological "seat-of-the-pants" innovations that have had major impacts on science.




1700
1750
1800
Big Telescopes
Laws of Motion
Gas Laws
Leyden Jar
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Oersted Experiment
ZOOLOGY
BOTANY
Living Cells
Cytology
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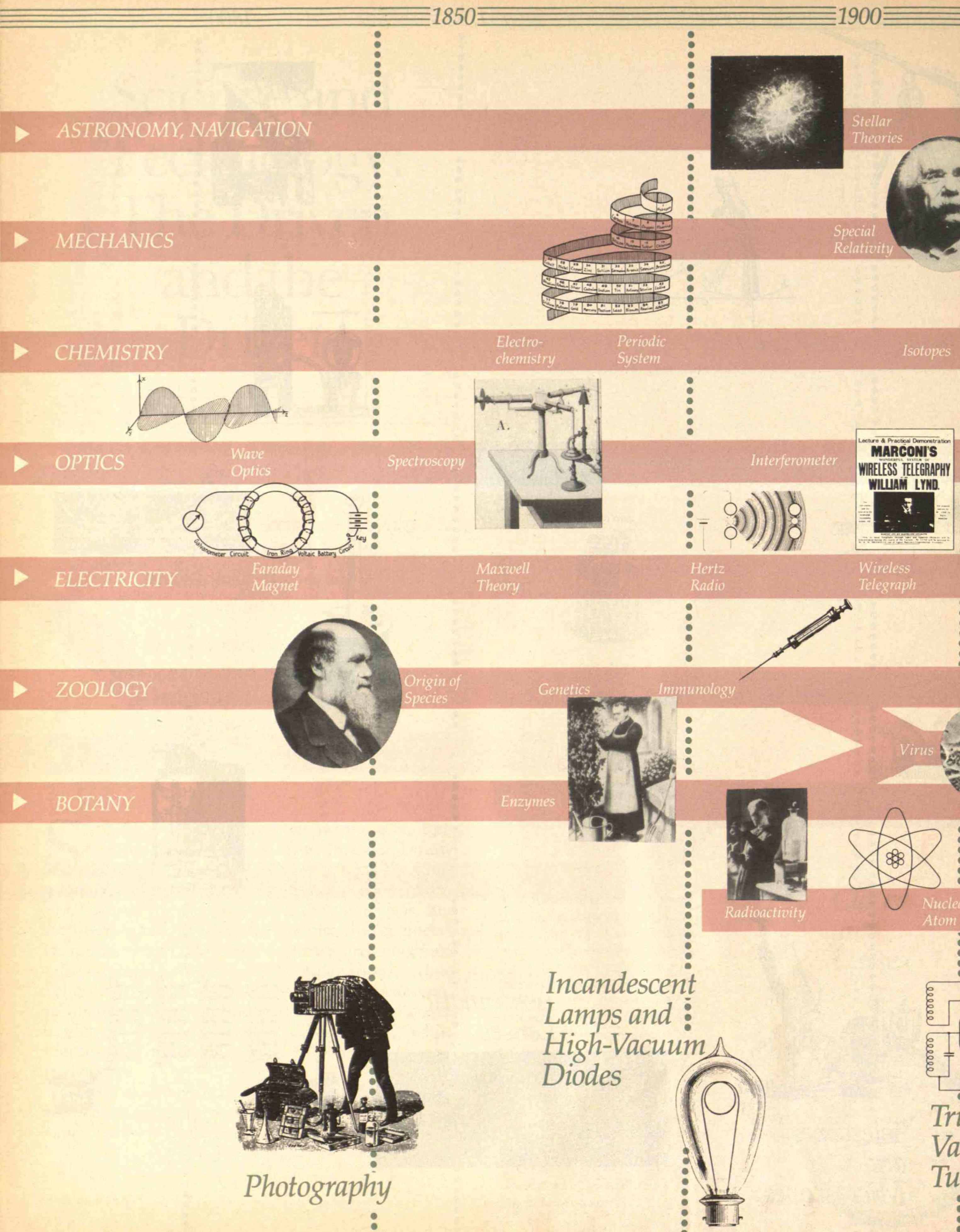
Achromatic Lenses
Voltaic Cells



1850
1900
ASTRONOMY, NAVIGATION
Stellar Theories
MECHANICS
Special Relativity
CHEMISTRY
Electro-chemistry
Periodic System
Isotopes
OPTICS
Wave Optics
Spectroscopy
A.
Interferometer
Lecture & Practical Demonstration
MARCONI'S
WONDERFUL SYSTEM OF
WIRELESS TELEGRAPHY
WILLIAM LYND.
Galvanometer Circuit
Iron Ring
Voltaic Battery Circuit
Key
ELECTRICITY
Faraday Magnet
Maxwell Theory
Hertz Radio
Wireless Telegraph
ZOOLOGY
Origin of Species
Genetics
Immunology
Virus
BOTANY
Enzymes
Radioactivity
Nuclear Atom
Incandescent Lamps and High-Vacuum Diodes
Photography
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JANUARY 1985

MIT

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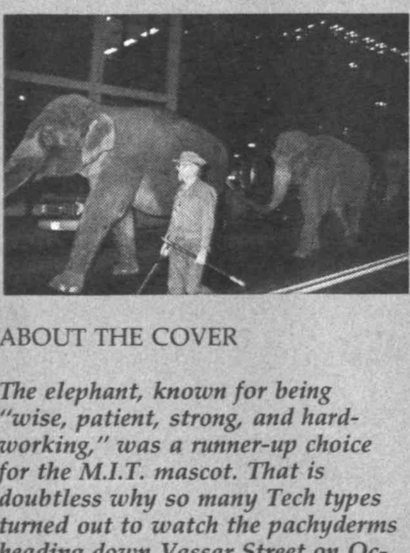


ABOUT THE COVER

The elephant, known for being "wise, patient, strong, and hard-working," was a runner-up choice for the M.I.T. mascot. That is doubtless why so many Tech types turned out to watch the pachyderms heading down Vassar Street on October 17, on their way to Boston Garden. Kept from its berth near North Station by fire damage, the circus train parked adjacent to campus. Photos by Peter Mui, '82.

STUDENT VIEW

DIANA BEN-AARON

The Brass Rat: Ticket to a Love/Hate Relationship

"Actually, ILTFP, but I'd never admit it to anyone," Lisa Mistler, '82, wrote in *Technique* 1982.

"My first husband always wore his Brass Rat, but refused to give any money to M.I.T." That's another variation on the theme of love/hate relationships with M.I.T.

I've seen a broad range of alumni reactions to the Institute in my three and a half years here, but two graduates in particular stand out: Paul and Jim:

Paul was a tutor in the Concourse program my freshman year. Although he had only been here a year, he had already decided the Institute had no redeeming virtues. He significantly accelerated the disillusionment process for the 60 Concourse freshmen by repeatedly telling them so.

Spring term, most of the Concourse class took 6.001, the introductory computer programming course for non-majors. They came in with their first program printouts in their hands and a look of unparalleled achievement on their faces, only to be told by Paul that 6.001 was a waste of time. "Why should I take that course, when I can teach myself everything in it?" he said.

Like many people critical of organized education, Paul was wrong. First, it is difficult to learn a subject independently at the pace of an M.I.T. course, and impossible to learn four or five things at once at that speed and depth. Second, a great deal of what we learn here is problem-solving, and many of us learn it best by watching instructors solve problems in lectures or recitations. What's more, the ability to complete an organized course is an achievement in itself. But to freshmen accustomed to believing upper-classmen, the statement seemed plausible.

I still can't figure out why Paul hated M.I.T. so much. He got a full corporate scholarship, which shielded him from the slings and arrows of the Financial Aid Office and high bills. Yet he constantly assured us that he could have earned a more valuable degree more cheaply at his state university. What's more, he lived in a fraternity, so he was not one of those whose first experience at M.I.T. was one of rejection, nor one who was getting no support from the members of his living group.

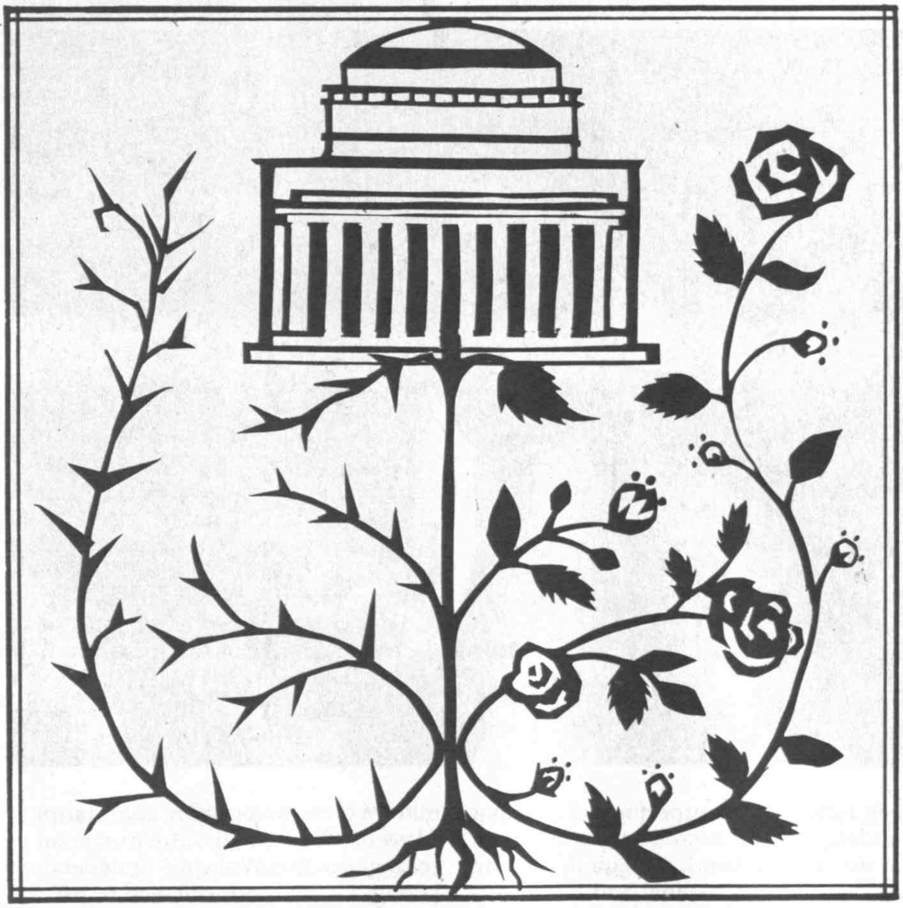
He chose to major in the subject his father taught at another university, and placed out of the first four courses in the department. This left him space to take everything he was interested in, including courses he needed for medical school. He spent one term at a college on the West Coast, and when he came back, I asked if the experience had made him more radical. "No," he said. "It got all that out of my system out there. Now I'm ready to settle down and join the medical establishment."

"Anyway," he went on, "I'm supposed to be very respectful of M.I.T. right now because I'm being allowed to live in my fraternity an extra term as a graduate resident even though I graduated in December." The hand was still feeding him, and he felt some responsibility to bite it less often and with less vigor.

Paul is now in medical school, and he is probably still running down the col-

DIANA BEN-AARON, '85, A MATERIALS SCIENCE AND HUMANITIES MAJOR, IS THE EDITOR-IN-CHIEF OF THE TECH.

He is in medical school, probably still running down the college that helped him get there.



lege that helped him get there. There is nothing wrong with victims of the "Institute screw" condemning M.I.T., but many who have enjoyed considerable freedom also feel cynicism is *de rigeur*.

"And Now for Something Completely Different . . ."

I don't think Jim ever had time to analyze his relationship with the Institute. When I was a freshman, he was a graduate student who still did his schoolwork in the Concourse lounge, just as he had as a freshman.

Jim worked in the Concourse Lounge because he had nowhere else to go. Throughout his career at M.I.T., he commuted from his family's farm some 45 miles away, and as a graduate student he did his thesis at a company 30 miles away in a different direction. There was a mattress in one room of the lounge, and when he didn't have time to drive home and back, Jim slept there.

Sometimes other graduate students would come over to the lounge to work with him, but they always went back to their apartments to sleep long before Jim had finished working. Jim worked harder than most of us will ever see anyone work again, filling blackboards, notebooks, and circuit boards in his quest for the right answer. Although no longer a Concourse tutor, he was never too busy to answer our questions when we got stuck on problems late at night after our tutors had gone home.

"He always studied harder than everyone else just to do as well," we were told by another Concourse alumnus, returning on a visit. "When we took the digital design lab together, the rest of the group's projects looked like birds' nests, with the wires sticking out everywhere; Jim's on the other hand, were beautiful, with all the wires tucked in and all the colors matching. He spent a lot of time making everything neat and easy to follow, but the other guys walked away with the top grades."

On the other hand, he added, Jim's perserverance made him outstanding at practical, real-life engineering. Jim had been heavily recruited by several companies and was considered an outstanding member of his co-op team.

I remember a day Jim walked in looking distraught. "Have any of you seen my thesis?" he asked us. The entire first draft of his master's thesis had disappeared from his briefcase in the lounge, he explained. The mystery was the talk of the Concourse freshmen for days: Why would someone do a thing like that to Jim? Personal competitiveness? Industrial competitiveness? After all, the other alumnus had said Jim's bachelor's thesis contained an original design so revolutionary it was kept in a safe instead of in the library.

The thesis never turned up. After a few weeks of searching and worrying, Jim sat down to reconstruct it. "I guess there's nothing I can do about it. I didn't think I'd graduate this term anyway," he said. Eventually he did finish the report, get his master's and go to work full-time in industry. He still visits M.I.T. now and again, and he always seems to be smiling, as if he had known all along that what he learned from the Institute would stand him in good stead.

These two alumni represent the extremes of feeling about the Institute; most fall in between. "I'm glad I did it, but I wouldn't do it again," seniors say in the yearbook and newspaper at graduation. I can only guess what I will think of M.I.T. by the end of this year, but I know which end of the spectrum I would prefer to inhabit. □

ILLUSTRATION: ELIZABETH SLOTE

National Alumni Conference Celebrates Voluntarism

The National Alumni Conferences, a chance for Alumni Association staff, active alumni volunteers, and members of the Institute faculty and administration to establish contacts, exchange information, and share concerns about the future of M.I.T., are also the occasion for recognizing at least a portion of the many volunteers who serve the Institute in countless ways.

Bronze Beaver: Alumni's Highest

☐ **E. Milton Bevington, '49**: (president-elect of the association) whose tireless efforts include serving as vice-president of the association Board of Directors; chair of the Alumni Fund Personal Solicitation Program in Atlanta; and many years of work on the M.I.T. Leadership Campaign in Atlanta.

☐ **Florence (Hon.) and Walter Smith, '28**: service over some 50 years, much of it focused on the Class of 1928, which has consistently outperformed all other undergraduate classes in participation in the Alumni Fund; and jointly serving as chair of the Cardinal and Gray Society. Their unprecedented joint Bronze Beaver recognizes that they have been inseparable in their service to M.I.T.

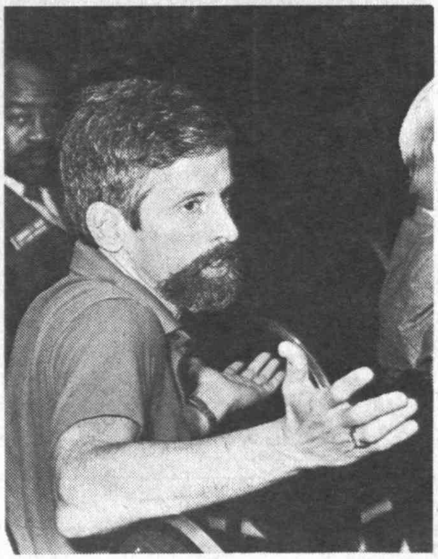
☐ **Peter M. Saint Germain, '48**: member of the Sponsoring Committee for the Economics Department, the National Business Committee, and the Corporation Visiting Committee for the Center for International Studies; he worked for the Council for the Arts in New York City and has been active in the Alumni Fund and other fund raising. As chair of the M.I.T. Alumni Center of New York for the past three years, he convened a new Advisory Committee to initiate activities; he is the newly appointed chairman of the Alumni Fund Board.

☐ **Elisabeth M. Drake, '58**: a member of the Corporation, several Corporation Visiting Committees, and national committees of the association; contributor to Class of 1958 activities; instrumental in setting up the Women's Independent Living Group and still active on the WILG Board; and a life member of AMITA, working on the Executive Board, the High School Visiting Program, and Career Conferences.

☐ **Thomas F. Creamer, '40**: served his class in every area; member of the Educational Council; officer, director, and chairman of the M.I.T. Alumni Center of New York; vice-president of the association; member of the Corporation and several Corporation Visiting Committees; and work with the Office of Resource Development.

☐ **Alice Kimball, '36**: maintaining and fostering the ties among M.I.T. alumni since her graduation; secretary of the Class of 1936 from 1961 to the present; active member of AMITA, including holding most offices; leadership in the Hartford alumni community.

PHOTOS: MARIO SCATTOLONI



Eight Lobdell Awards

☐ **Sandra G. Yulke, '74**: for dedicated service on behalf of the Class of 1974, AMITA, the Educational Council, and the Alumni Fund.
☐ **Edwin F. Brusch, '63**: leadership of the Alumni Fund Personal Solicitation Program in Boston; contributions to the Alumni Fund Board and the Alumni Council.
☐ **Paul Fricke, '61**: active service to the M.I.T. Club of Chicago, the Alumni Fund, and the Educational Council.
☐ **Robert P. Fried, '46**: for more than 30 years of dedicated service to the M.I.T. Club of the Hudson Valley, the Alumni Fund, and the Educational Council.
☐ **Vincent A. Fulmer, S.M.'53**: an active role with the Enterprise Forum.
☐ **Lee Gagan, '61**: innovative stewardship of the M.I.T. Enterprise Forum of New York.
☐ **David R. Wadleigh, '38**: tireless support of the M.I.T. Club of Cape Cod and the Class of 1938.
☐ **Harris Weinstein, '56**: leadership of the Alumni Fund Personal Solicitation Program in Washington, D.C. and other efforts in behalf of the Alumni Fund.

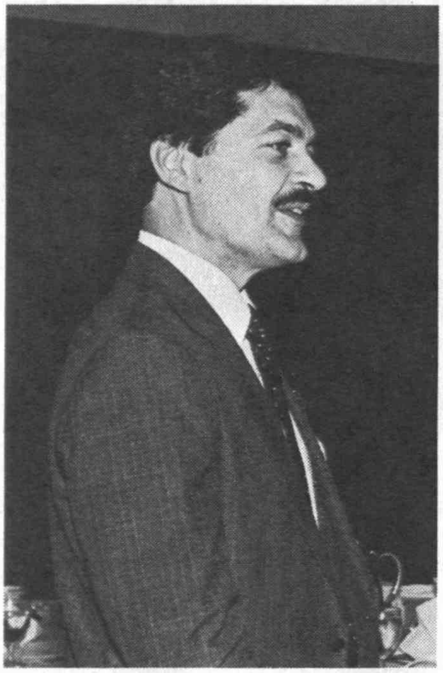
Four Presidential Citations

☐ **M.I.T. Club of Harford Spring Telethon**: held in each of the past six years, marked by an "infectious spirit of warmth and conviviality among the participants"—a uniquely successful annual event.
☐ **M.I.T. Club of Northern California**: a model of structure, organization and program planning; in 1983-84, a record-setting year, it boasted 33 programs run by 63 active officers and directors. The club combines the key elements of good leadership identification, involvement and renewal; diverse and creative event

Continued on page A6

AT THE TORONTO GATHERING: (Facing page, foreground) John Buss, '26, and Max Coutts, '39, in a relaxed but serious exchange. (Above, clockwise from top left) Robert Blake, '41, making a point. The Toronto host committee taking a bow: (clockwise from top left) David Grant, '80; Warren Baker, '64; Jick Chan, '69; Max Coutts, '39; Greg Coutts, '77 (president of the M.I.T. Club of Ontario); and Donald Taylor, '50. Ken Rosett, '42 (facing camera) debating a point with Robert Mann '50 (immediate past president of the Alumni Association). And Michael Bertin, '63, contributing to a lively discussion. The pictures were taken as alumni participated in sessions on the work of the Educational Council, the Alumni Fund, and regional and class activities, and heard speeches and a panel discussion on the world economy. Art gallery tours rounded out each half of the 1984 NAC.






DALLAS: (Clockwise from top left) Russell Cox, '49, chairman of the M.I.T. Enterprise Forum of Cambridge, participated in a panel discussion on entrepreneurship, as did Allan Bufferd, '59, associate treasurer of the Institute. This unidentified graduate's obvious enjoyment of the program is what the NAC is all about. Frank Reedy, '78, president of the M.I.T. Club of Dallas, the conference hosts.

Continued from page A5
planning; major emphasis on membership; a professionally printed newsletter; and special efforts on scholarships, directory, student employment and high school leadership award programs.

☐ **M.I.T. Chemists Club**: engages a broad membership of alumni, faculty, students and postdoctoral fellows; held a Convocation in 1983 which attracted more than 100 participants to a variety of socially and professionally-oriented events; through regular meetings, newsletter, and career forums it provides an example for other departments.

☐ **San Diego Personal Solicitation (Telephone) Program**: since the introduction of this fund raising format in 1980, the alumni of San Diego have consistently been among the most successful, in terms of the number of volunteer callers, dollars raised, and percentage of gifts upgraded; the San Diego PS(T) program doubled from 1980 to 1983. ☐

A Humanism for Enlightened Engineering

James Ham, Sc.D. '47, holds graduate degrees in electrical engineering from M.I.T., and was formerly president of the University of Toronto. He spent 1983-84 at the Brookings Institution.

The following are excerpts from the Richards Lecture delivered by JAMES M. HAM, Sc.D.'47, professor of science, technology and public policy at the University of Toronto, at the 1984 National Alumni Conference in Toronto, on October 13, 1984. The Richards Lecture is given annually to focus on the responsibility of alumni to speak out on public issues.

The wealth of mankind has been won in significant measure with the backs, lungs, and spirit of workers—slaves, immigrants, and citizens. The history of accidents and the diseases of workers provides a fascinating approach to social history, and it has been public involvement with occupational health and safety that has in the past decade led me to a deep interest in the place of human skill and talent in structuring our modern technologies.

Since the industrial revolution there has been a persistent and continuing fragmentation of work, a conscious delimiting of the human skills required in the operative relations of many workers to the technical systems of which they are part. Associated with this continuing process of fragmentation and deskilling has been a traditional model of managing the work force—a model based on job design through highly specific tasks for which performance expectations and compensation rates are clearly codified. Labor is a factor to be managed as a variable cost. The keywords of this paradigm are control and efficiency.

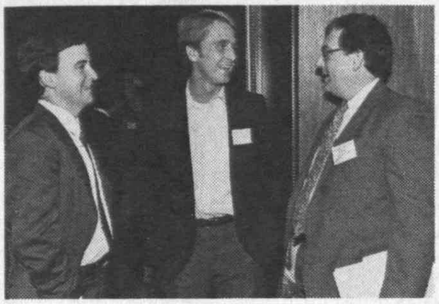
There has been emerging in recent decades a mode of work-force management that has been called the commitment model. It is best illustrated for continuous-process manufacturing by the organization of work teams that share a performance objective, such as system maintenance, and are free to commit their individual capabilities by group determination. Multi-skilling, re-

PHOTOS: MARIO SCATTOLONI, NAN VROOM

newal training, and participative opportunity are characteristics of this *modus operandi*. Management structures are less hierarchical and employees, customers, and the public as well as ownership are acknowledged constituents. Compensation is based on (the employees') skills and on performance.

The conceptual stimulus for this paradigm of job enrichment and group autonomy has come not from engineers but from social scientists. Engineers and technologists have not produced any methodology for using to the full the abilities and skills of human beings. They (or we) are locked in the paradigm of mechanization, automation, robotization, computer-aided manufacturing, and expert systems based on artificial intelligence. . . . Can there be a new paradigm of supporting and developing human talent?

I believe that a true humanism for elightened engineering may yet be found in a profound concern for the nature of the work we require others to do. □



DALLAS: (Top, left to right) Dennis Gorman, '81, and Colin Shepherd, '81, met with William Hecht, '61, executive vice-president of the Alumni Association. (Bottom) Paul Gray, '54, and Priscilla Gray (center) greet one of the spouses of M.I.T. alumni who took part. President Gray reported on the state of the Institute and showed a videotape on the 270 design competition.

We have been part of an educational adventure which links us together and calls us back to support the Institute.

Keeping the Connections Alive

The first installment of the 1984 National Alumni Conference, meeting at the elegant, old-world King Edward Hotel in Toronto September 21 and 22, gave Mary Francis Wagley, '47, her first formal opportunity to address an alumni group since she took office as president of the Alumni Association in June. Her remarks were also presented in Dallas October 12 and 13 at the second half of the conference.

"We have been part of a great educational adventure which links us together across the years and calls many of us back to give our time, our energy, our skills and our money in support of the Institute," she said.

M.I.T.'s commitment to diversity is important to Wagley, who told her Toronto audience that "you and I are evidence of that diversity. If you are Canadian, you are one of 7,000 alumni who live beyond the borders of the United States. If you are an alumna, you are one of some 5,000 women who are graduates of M.I.T.

"And there is a diversity beyond nationality, sex and race," she continued, quoting recently-retired Director of Admissions Peter Richardson. When asked to characterize this year's freshman class, Richardson said "They are highly intelligent; they are very energetic; and they love math." Beyond that, he added, "They are the most diverse bunch of kids you could imagine.

"That mix of students," Wagley continued, "creates a rich and exciting environment in which to learn and grow."

Turning to the Alumni Association, Wagley talked first of the remarkable growth of the Enterprise Forum, which is now regularly in touch with 4,000 people in the Boston area and thousands of others nationally in eight locations.

Wagley emphasized that it is the symbiotic relationship between the professional staff and dedicated volunteers that makes the M.I.T. Alumni Association noteworthy. That fact was brought home to her by a well-informed editor from *Women's Wear Daily*, who interviewed Wagley on her special role as the first woman to head the association.

Speaking of that editor, Wagley remembered that "she was impressed with the reaching out by the Institute to individuals such as myself, so that we would remain within M.I.T.'s sphere of influence, to our mutual benefit. I could only nod in complete assent."

Bronze Beaver Awards went to (top) Peter M. Saint Germain, '48, shown receiving his award from Mary Francis Wagley, '47; (bottom, clockwise from top left) E. Milton Bevington, '49, president-elect of the Alumni Association; Walter Smith, '28 and Florence Smith (Hon.); Elisabeth M. Drake, '58; and Alice M. Kimball, '36.

David Saxon: From Terrified Freshman to Elder Statesman in 45 Years

David S. Saxon, '41, remembers that he was "absolutely terrified" when he first came to M.I.T. as a freshman in 1937. His feelings were not so different a year ago when Saxon returned to M.I.T. after 37 years at the University of California, during which he rose through the faculty ranks to become a dean, then chancellor, and finally president. In opening this interview with Technology Review, *Saxon expressed his pride and pleasure in his opportunities to serve "two of the greatest educational institutions in the world"—a "singular blessing," he said. Saxon then discussed with us his reactions to the M.I.T. of today and his hopes for his tenure as chairman of the Corporation.—J.M.*

Saxon has the advantage of being a member of the "family" with the perspective of an outsider.

"I was invited here to provide a view not based dominantly on M.I.T. experience."

TR: After 40 years at the University of California, you have returned to M.I.T. saying that it holds a unique place among institutions. What is this uniqueness?

Saxon: It is no single thing but a combination of characteristics. But if you press me to select that feature which seems to me most remarkable, it would be the student body. Here is just an extraordinary, remarkable concentration of enormously talented young men and women who have a strong sense of what they want to do, of where they want to go, and of their own values.

A second feature is the geographical containment of the place. If you compare us with other institutions of similar size, there is a striking difference. M.I.T. is contained in just over 100 acres, while most of them are spread over a much larger area. The small size of the Institute adds to the intensity and interrelatedness of life here.

A third distinguishing feature of M.I.T. is its faculty, the quality of which is outstanding—concentrated excellence. We have roughly 1,000 faculty members here. Other institutions might have that many faculty members of comparable quality but they also might have another 1,000 who are not remarkable by any measure.

These statements about the quality of the students and the faculty may appear self-serving, but I think there is objective evidence to support them. Over the years, for example, you will find M.I.T. graduates disproportionately represented at the top levels of academia, government, and industry.

M.I.T. is also distinctive in the seriousness of its concern for the broad education of its students. Indeed, I know of no institution that has done better at closing the gap between humanities and the sciences. That may be a surprising statement, and I would not want to suggest that we have succeeded absolutely.

But that leads to another statement I can make about M.I.T.: it is one of the few places I know where relative accomplishment is not good enough, where people aren't satisfied to measure themselves by what other institutions are doing. It is a place in which there is a commitment to absolute excellence. Even if we are doing better than everybody else, people here don't think that is necessarily good enough.

TR: Some of these qualities you must have expected, but some surely have surprised you upon returning to M.I.T. after a long absence.

Saxon: The surprise for me—and it is a very pleasant surprise—is the dimension of what I have just described. When I was a student here in the 1930s, many of these same characteristics were evident. But they not only have been maintained over these years but in some important ways enhanced, even while M.I.T. was becoming a broader institution with much more comprehensive programs.

There have also been very important changes in the campus, leading to changes in the character of student life. The athletic facilities were primitive when I was a student here—almost nonexistent. We had just a few dormitories and a single, rather inadequate library. There was very little extracurricular life.

All that has changed now.

Even more important, I find the attitude toward students totally different. I often use the word austere to describe M.I.T. as it was when I was a student. It was a tough, stand-alone environment that people thought was appropriate for the kind of education M.I.T. intended to provide. You couldn't get very much help from anybody. The Admissions Office picked the brightest kids they could, and it was sink or swim. They expected many to sink.

The campus is now profoundly different. Before I came back I couldn't conceive of the corridors filled with banners and of music groups performing in the Building 7 lobby . . . it is like being in the middle of a big city. In my day it wasn't like that, and I was quite unprepared for the change.

TR: Didn't being a member of a fraternity enliven your student experience?

Saxon: Well, we had a good time, but we very much felt that we did it on our own. And, outside the fraternities, I think many students lived very isolated lives.

Yet it was a tremendous environment

PHOTO: PETER MUI, '82

Federal support doesn't come free; indeed, I often find government more intrusive than business.

for learning, and the faculty were very serious about educating students. They expected a lot. If you really were interested in getting educated—and most of us were deadly serious about getting educated—this was a place to do it.

TR: Do you think that is different now?

Saxon: I am doing some advising this year and will know more about today's students by the end of the year. It seems to me that the incentives and the measures of performance are different. The measures were narrow when I went to school—numerical measures were used to rank students, with published dean's lists—a mixture of reward and pressure. Some of the pressure is less overt now.

But I never felt that M.I.T. failed to recognize unusual talent even if it manifested itself in ways that were hard to quantify, and that is still true. Furthermore, the pressure is still there, even if people are not always graded. Peer pressure is very strong—all the students are so good and so motivated.

TR: A year ago you were speculating that you were going to enjoy the experience of returning to M.I.T. Have those expectations materialized?

Saxon: Yes, probably more than we expected—and I speak for my wife, too. We were confident of how fine intellectually this place was going to be and how much pleasure our association with it would give us. What we didn't quite realize was how much we would enjoy the geographical compactness not only of M.I.T. but of the Boston area. Any place at M.I.T. is within walking distance of where we live, and we can walk—we never drive—to Boston.

TR: There is no full-time job as chairman of the board at most universities. What does your job as chairman of the Corporation mean? What's on your desk every morning?

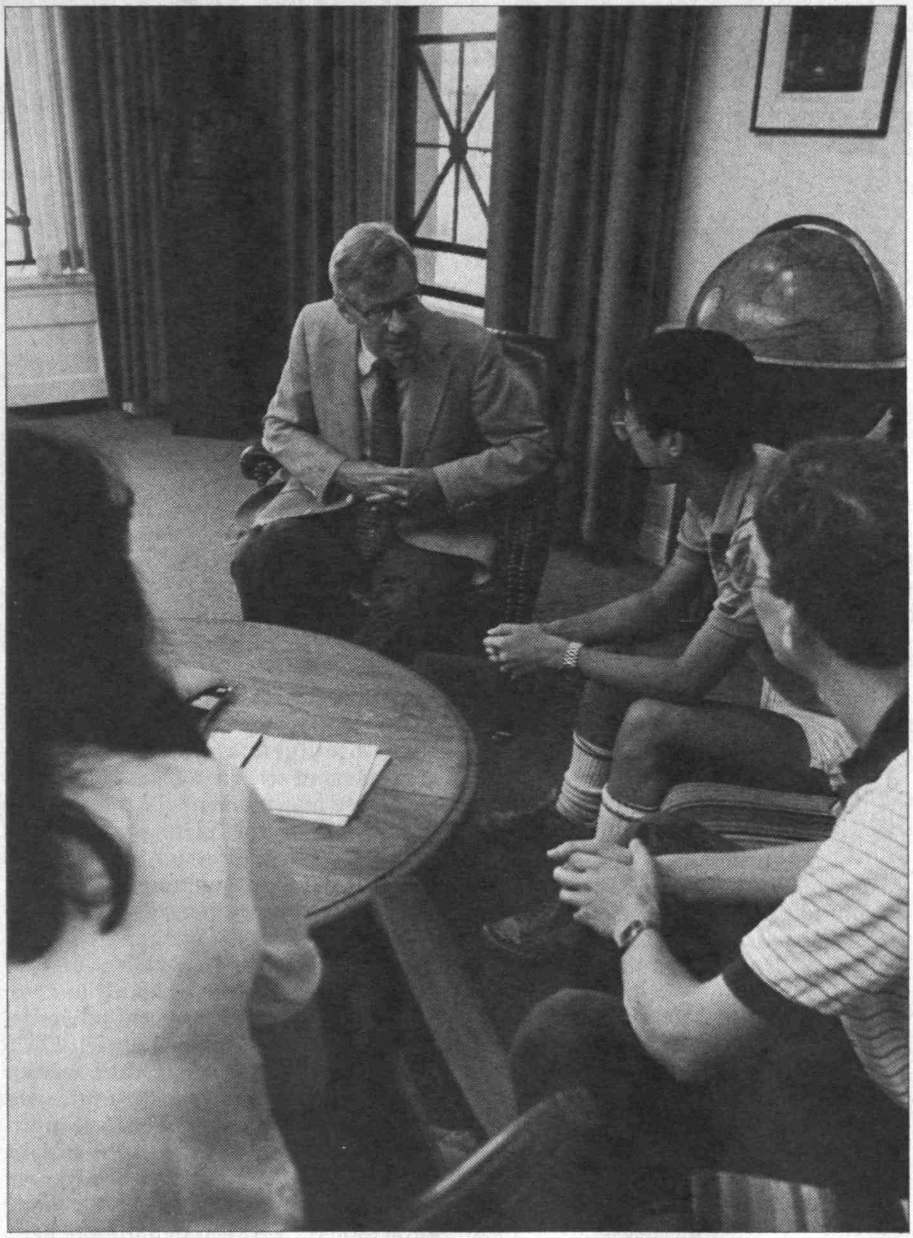
Saxon: The Chairman has three things to concern himself with. The first, of course, is the Corporation itself—a very large body, unusually large compared to the boards of trustees of other institutions. The chairman has a major responsibility to see that this large body does not become unwieldy, but remains vital and effective. The position requires more than just a convenor.

Then there are the visiting committees, invited by the Corporation to review the activities of the departments and of certain special domains. Those visiting committees exert a unique form of quality control at M.I.T.—identifying the important activities that departments ought to be engaged in, helping them get out of ones that are no longer important. The chairman's role in ensuring that this mechanism works effectively is vital.

A second obvious role for the chairman is in fund raising. In most institutions there is no substitute for the president in dealing with the most important benefactors. But at M.I.T. the chairman is a major officer, and donors are as interested in meeting with the chairman as with the president.

The third function of the chairman of the Corporation is acting as a consultant to the president and senior officers. In the past the chairman has usually been a president-emeritus who knows the Institute and its functions intimately, and it has been very useful for presidents to have that kind of support. But one of

PHOTO: FRANK REVI, '86



(Far left) Earl Lockhart, '34 chats with Shirley and David Saxon, '41, during the latter's first reunion weekend as chairman of the Corporation. (Left) Dr. Saxon keeps in touch with his constituents by serving as freshman advisor to Philip Chu, Jerrold Boxerman, (far right) and Livia Zien.

the reasons I was invited here was to provide a point of view that would not be based dominantly on M.I.T. experience. I think that is valuable as long as the president gets advice when he wants it and not when he doesn't. I'm very conscious of the difference between the chief executive officer, the president, and the chairman of the board. I spent a lot of years as a president keeping my chairman at bay. That's not a line I'm interested in crossing.

I think I am supposed to be what people often call an "elder statesman." I'm not sure I want to think of myself as an elder, but I'm pleased by the notion of being a statesman, and the combination doesn't sound bad to me.

TR: You do speak out independently on issues that concern M.I.T. very broadly.

Saxon: Yes. For example, I've given a number of talks on the relationships between universities and industry, on the importance of a broad education, and on other issues facing higher education.

I've said that M.I.T. is an exemplar when it comes to university-industry relations. Its involvement with industry is deeper than that of any other U.S. institution; the fraction of its budget provided by industry is two or three times the national average. M.I.T. has been more innovative, more committed, and more comfortable with these relationships than most universities.

Some of the dangers to universities in close relations with industry are exaggerated. There is always the need to look at the balance of benefits and risks. We tend to take federal support for granted, forgetting that it doesn't come free; indeed, often I find the federal government substantially more intrusive than business as a research partner. With an industrial sponsor you know what his purposes are and you can usually deal with them. Government's interests are broad, much more complex, and sometimes even contradictory—for example, the controversy about the publication of information that is unclassifed but "sensitive." So it seems to me that this tendency of many to believe that university interaction with the federal government is inherently benevolent and that interaction with industry inherently threatens academic values is quite wrong.

One of my great concerns is that in a world growing ever more technological, scientific and technical experts have to be broadly trained. And complementary to that—and more difficult—is the need to see to it that everyone is scientifically and technologically literate. Too many people fear technology. They don't understand it, they can't tell what makes sense and what doesn't, and they become victims of our technological society instead of partners in it. This concern represents a major challenge to education and to society, and I want to work on resolving it.

Another major challenge for education is to bring into our institutions those who have been traditionally under-represented there—women and minorities. It's exactly 30 years since the landmark decision, *Brown vs. Board of Education*, in 1954. When that decision was handed down, I had the simple-minded notion that we would quickly see integrated schools and a uniform standard of education. I was wrong; 30 years later we're still struggling with that issue.

So I feel no shortage of important things to work on, and I delight in the chance that this new job gives me to form and share my ideas with so many bright, committed people. □

PHOTO: PETER MUI, '82

Faculty Moves to Cap EECS Enrollment

The faculty has approved a plan to limit the number of students majoring in Course VI, Electrical Engineering and Computer Science. But since measures taken over the past year have been effective, in arresting the spiraling EESC enrollment, no restrictions on majors will be imposed for the freshman class entering in 1985.

The plan, as approved, set a series of goals for EECS sophomore enrollment: it must drop from 380 in 1983 to 350 in '84; then to 310 in '85; and down to a steady-state 270 by 1986. When the registrar reported 356 sophomores in EECS last October, the Institute breathed a collective sigh of relief. The Committee on Undergraduate Admissions and Financial Aid (CUAFA), charged with implementing the plan, announced that it considered Step One to be achieved.

CUAFA will meet this spring to look at the early data on the majors indicated by the current freshmen. If the figure for Course VI is not close to 310, the committee may instruct the Admissions Office to offer restricted admission to a proportion of the 1986 freshman class.

The restriction would be in the form of a letter informing an applicant that he or she could enter M.I.T., but would never have the option of majoring in EECS. Estimates for even a worst-case scenario indicate that no more than one-quarter of the admitted students would be so restricted.

CUAFA and the Admissions Office would be responsible for deciding how the restrictions are imposed on the admitted class, subject to four conditions: First, although reducing the undergraduate enrollment in EECS is important, the primary goal of the admissions process must be to assemble the best possible freshman class. Second, restricted admission must be distributed evenly over the class, so that it is clear that it does not in any way represent an inferior ranking. Third, the admission decisions are to be made initially without any regard for the restriction process. And fourth, information on career interests will be considered in making restriction decisions, but the stated field of interest in itself will not be a major factor in deciding whether a student is offered restricted admission.

Working in the shadow of the Dome, Arthur Smith, chairman of the faculty, prepares to lead his colleagues to consensus on EECS enrollment.

The crisis in Course VI came to a head last year. Having experienced steady growth since 1976, the department found itself enrolling 35 percent of the sophomore class in September, 1983. The result for the department's faculty was that the balance among undergraduate teaching, graduate teaching and research was dramatically skewed. But the worst seemed yet to come; already strained to the limit, they faced projections for 1984-85 ranging from 404 to 425 sophomores.

The department requested action to limit the influx, but a general faculty meeting in December, 1983, found all the proposals then on the table unacceptable. Recognizing the gravity of the situation, however, the Institute launched an all-fronts effort to bolster the resources in EECS while encouraging freshmen to consider other majors.

The process by which freshmen declare majors was changed to increase the role of advisors. The Career Services and Preprofessional Advising Office launched *How to Get There From M.I.T.*, a booklet of articles by alumni which illustrate how many different career paths can lead to any one goal, such as professional involvement with computers.

New programs and degrees were introduced which engage many of the same skills and interests as Course VI: a materials science option which emphasizes electronic materials; a psychology degree in cognitive science (that department's first undergraduate degree) which includes the study of artificial intelligence; and a degree in management science which emphasizes data base management. Two more programs are in the planning stages: a mathematics option which includes many electives in computer science and a physics option with a substantial electrical engineering component.

Back at EECS, the number of new transfer students was reduced to zero, and faculty members from other departments were enlisted to teach EECS subjects and supervise EECS senior theses. In addition, the Institute was able to meet the department's requests for additional funds and faculty, and the Genrad Foundation offered $50,000 per year for five years to support visiting professors. (However, department head Joel Moses, Ph.D.'67, emphasizes the fact that there are very few candidates available who meet the hiring standards in EECS, and in any event, there are overwhelming space constraints on his department.)

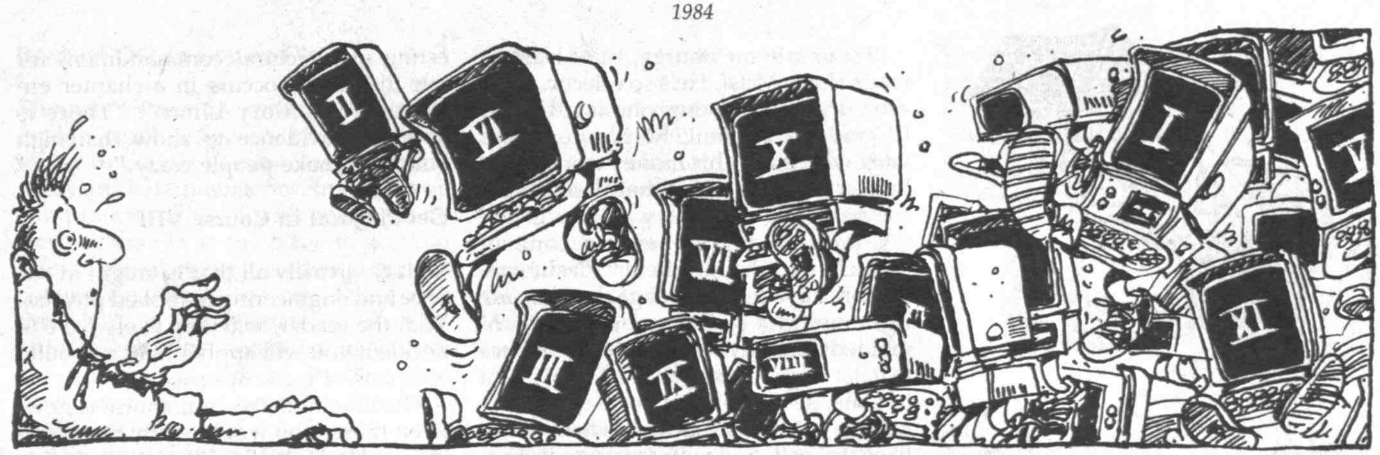
Even without restricted admissions, the pressure for an equable distribution of undergraduates among all departments is influencing the M.I.T. admissions process. According to Professor Kenneth Manning, chairman of CUAFA, the Admissions Office will no longer assemble a freshman class which is simply an aggregate of individuals. Instead, it will consider the shape of the freshman class as a whole right from the start, seeking a diversity of skills and interests while maintaining the traditional math and science requirements. □

PHOTO: FRANK REVI, '86

COURSE VI
THE ALTERNATIVES

Give a Hoot, Don't Compute

BY JOSEPH J. ROMM, '82
Excerpted from The Tech, *1984*



It is not impossible that a few of the 405 sophomores projected to enroll in Course VI this fall were persuaded to try other options by the 17 columns by JOSEPH ROMM that appeared in The Tech *between February and April, 1984—decision time for many. Romm is a graduate student in physics, and a sampler of his columns, alternately outrageous and informative, is reprinted here.*

Majoring in Course VI May Prove Hazardous to the Health of M.I.T.

You are among the brightest students in the entire country. You are not actually one of them, but you are among them.

Yes, this is M.I.T., the school the Wizard of Oz probably had in mind when he told the Scarecrow, "I can't give you brains, but I can give you a diploma."

You want an M.I.T. diploma, and the job security it brings. You want to open meetings by banging your brass rat on the table.

I am trying to convince you in this series of columns not to major in electrical engineering or computer science. Potential VI students must realize that you can achieve the same end—fascinating computer-related work and good money—in many departments other than Course VI.

Civil Engineers Are Mellow

I begin with Course I. "A" had her own special reason for going into Course I: It was the engineering department that made the least use of calculus. Bear that in mind, potential Course VI majors who cannot integrate the square-root of sin[exp(e/2)] from zero to the diameter of the universe in furlongs.

"B" is concerned with worldwide issues of the future of humanity. He works part-time trying to prevent nuclear war, and he still has time to row crew and go to Steve's Ice Cream every so often. And he chose Course I. Bear that in mind, potential Course VI majors who do not want to work for the Defense Department. In addition, both Ms. A and Mr. B are whizzes with computer modeling, especially systems dynamics.

Course I really covers a lot of material, from ecology to bridges to dams to computers to why you should not fly into San Diego Airport if remaining distinguishable from the runway is high on your list of priorities.

Pick Course II for Power

Course II is power, cars, and control. Let me illustrate with the story of "D." In high school, he assembled a jeep from the parts of more than a dozen cars. At M.I.T., he had a brief fling with the biomedical engineering facet of Course II. Then Mr. D found computers and control, which is the use of electronics for regulating machines. This was Mr. D's Nirvana. He used to say that applying computers and control to the design of cars was more fun than self-abuse. Now, *that* is auto-eroticism.

"F" is a Course II major with a potential job offer for designing the hardened mobile platforms for the Midgetman single warhead intercontinental ballistic missile. Mr. F is a MechE with an innate desire to build things that destroy other things. Not surprisingly, one of his hobbies is war-gaming, and, even less surprisingly, his most recent favorites are the auto-dueling game, Car Wars, and Nuclear Escalation.

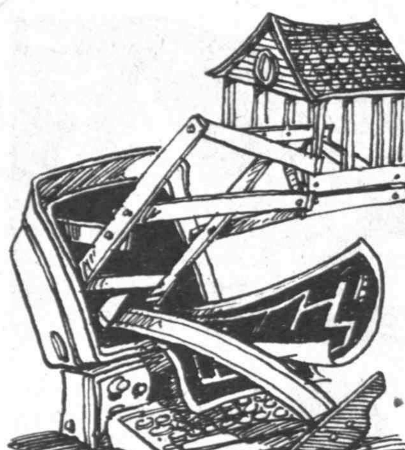
Course II is for Power, Cars, and Control. On the other hand, what potential Course VI major isn't?

Better Living Through Chemistry

Today my topics are Course V and X, Chemistry and Chemical Engineering, respectively.

Let me start with Course V. At last, a pure science, and with it the two main benefits of studying a science at M.I.T.: 1) The chance to gain tremendous insight into the workings of the universe; and 2) an amazingly small number of departmental requirements.

Majoring in Course IV is like having AB blood; it's a good idea, but basically you have to be born that way.



The key to understanding a science at M.I.T. is that the problems asked in advanced science class are so difficult that they can only be solved if you know the answer ahead of time.

For the sake of smooth transition, the key to understanding an advanced engineering class at M.I.T. is that although the problems are conceptually easier, the number of "correct" answers is limitless. The difficulty lies in determining which of a variety of approaches will achieve the optimum answer. Course X, however, is considered by many to be the most difficult department at M.I.T., perhaps because it combines the toughest aspects of both pure science and engineering.

Course V and X are for applied quantum mechanics, applied chemistry, biochemistry, biomedical engineering, fuel and energy engineering, polymer research, or for learning why death is the state of being in thermal equilibrium with the dirt.

Materials Science for the Surface Oriented

Course III people are surface-oriented people, which is not to say that they are shallow and superficial, although many are. MatSci people, as they fondly refer to themselves, deal with the surfaces of plastics, metals, ceramics, and semiconductors.

"K" is into metallurgy, or at least he reads *Heavy Metal*. He's so eclectic, however, that even though he is a Course III graduate student, he is a computer whiz who makes his money working for Project Athena writing thermodynamics software.

Conducting polymers are one of MatSci's exciting new fields. Plastic conductors have the advantage that they are light-weight and can be injection-molded into any shape. Mr. "I" hopes to get a huge grant from the Department of Defense to build a disc-shaped high-voltage plastic capacitor—what Mr. I likes to call a counterpersonnel Frisbee—to terminate life on this planet, currently one of the Defense Department's top priorities.

Course III is a very underrated major. Potential VI-1 majors interested in transistors could just as easily study electronic materials in Course III. The co-operative program with industry is growing rapidly, as many of the previously mentioned people can attest when they sober up a bit.

Go IV for Graphics

To some extent, trying to convince eager freshmen to major in Architecture is like trying to convince people to have AB blood type; it's a darn good thing, but basically you have to be born that way.

Course IV does not just teach architecture, however, it also teaches the visual arts—photography, cinematography, and drawing. More significantly, if you are a potential VI major even vaguely interesed in computer graphics, you really must visit the Architecture Machine Group. The ArcMac, as it is called, does computer graphics so impressive that recreational pharmacologists at M.I.T. say that it is the best place to trip.

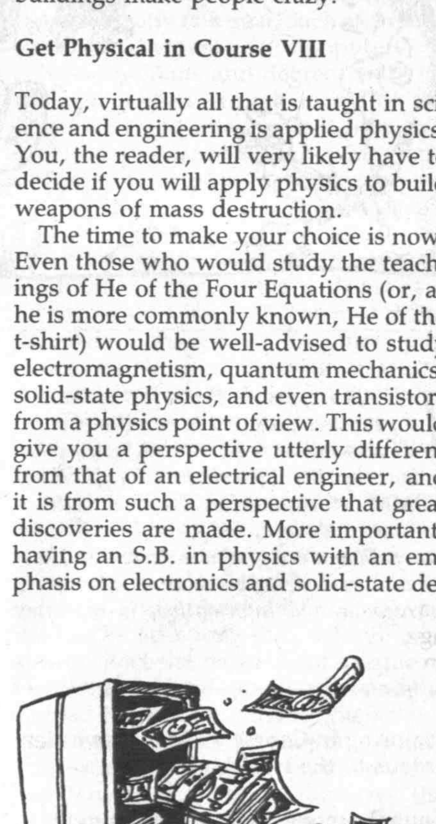
My old Course IV friend "J" says that would-be M.I.T. architects should read *A Pattern Language*, the bible of the M.I.T. Architecture Department.

A Pattern Language presents its commandments not in stone but rather in bold-face type. Perhaps the most interesting architectural commandment for our discussion occurs in a chapter entitled "Four-Story Limit": "There is abundant evidence to show that high buildings make people crazy."

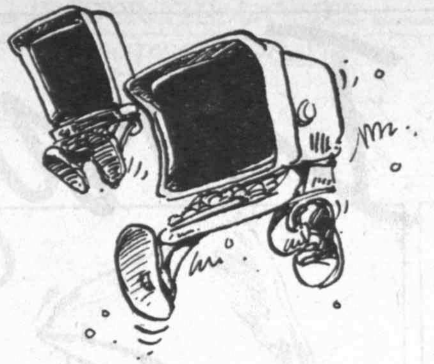
Get Physical in Course VIII

Today, virtually all that is taught in science and engineering is applied physics. You, the reader, will very likely have to decide if you will apply physics to build weapons of mass destruction.

The time to make your choice is now. Even those who would study the teachings of He of the Four Equations (or, as he is more commonly known, He of the t-shirt) would be well-advised to study electromagnetism, quantum mechanics, solid-state physics, and even transistors from a physics point of view. This would give you a perspective utterly different from that of an electrical engineer, and it is from such a perspective that great discoveries are made. More important, having an S.B. in physics with an emphasis on electronics and solid-state devices would also give you much greater career flexibility, to allow you to avoid the dark side of the Force.



I got this perspective from "S," a physics major who taught me that physics is not a field of study; it is a way of life, a religion.



Psyched Out in Course IX

The new Course IX undergraduate major in Cognitive Science offers an alternative to Course VI majors who want to study artificial intelligence. In fact, if you want to get involved with computer vision, Course IX is the place to go. You know a department is doing serious computing when you can take more than half of the restricted and unrestricted electives combined in Course VI, including the famous Structure and Interpretation of Computer Programs (6.001).

And do not worry that many of the applications of computer vision are defense-related, because many of those applications are for increasing the resolution of satellite-based technologies necessary for verifying arms control treaties with the Soviet Union. Remember, telemonitoring is the next best thing to being there.

Go XIV or XV for the Big Bucks

I want to start with Course XV, Management, because of its new SB program in Management Science, which has an Information Systems option, many of whose requirements can be satisfied by Course VI subjects. The Information Systems option is for potential Course VI-3 majors who want to make a huge amount of money working with computers and who have the foresight to realize that no matter how much they are interested in computers, they are likely to end up in management within five years of taking any computer-related job.

M.I.T. has one of the finest economics departments in the entire country. And Course XIV at M.I.T. is a great major: There are not many other courses in which you can simultaneously satisfy your departmental requirements and your humanities concentration requirement. Even better, since no two economists ever agree on anything, no one will ever know if you are a bold thinker or an incompetent boob. (The supply-side theorists are a prime example.)

Course XVI for Rockets, Weapons

Today's column is on Course XVI, aeronautics and astronautics, the course for planes, rockets, and weapons of all shapes and sizes. For potential VI-1 majors interested in working on things like guidance systems, Course XVI offers the Avionics option. Many requirements in this option can be satisfied with Course VI subjects, including the infamous combination of Circuits and Electronics (6.002) and Signals and Systems (6.003). Two of the best courses in lasers and optics in the entire Institute are offered in Course XVI. I even took one of them.

Course XVII is for Political Decisions

I know that a lot of you potential Course VI majors out there worry about nuclear war. Why not major in Defense and Arms Control Studies in Course XVII and try to do something about it? Your job prospects would be darn good, because rather than being just another wimpy political scientist, you would be proficient in science and technology issues. You would be a shoo-in to win a scholarship to some famous—cringe—liberal arts school or even get into a law school, such as—double cringe—the one up the river.

Course XVIII Has the Best Lecturers

Mathematics is a great major. The requirements can be satisfied easily and with great flexibility. More importantly, the professors in Course XVIII are among the finest lecturers—and poker players—in the Institute. This fact is well documented in the Course Evaluations Guide.

All of you potential Course VI-3 people who really want to make a lot of money writing software would do better to major in mathematics, particularly applied math. It could give you all the tools needed by an expert programmer, except perhaps for text processing, a gap you could trivially fill with a few Course VI subjects.

More importantly, you would not have to take all the yucky Course VI subjects that people like you loath.

The Pen Is as Mighty as the Terminal

Do you know who the highest-paid nonmanagement personnel are at most major computer companies? They are not the engineers and programmers. They are the in-house writers who do things like write manuals for the low, low price of $1,000 a day.

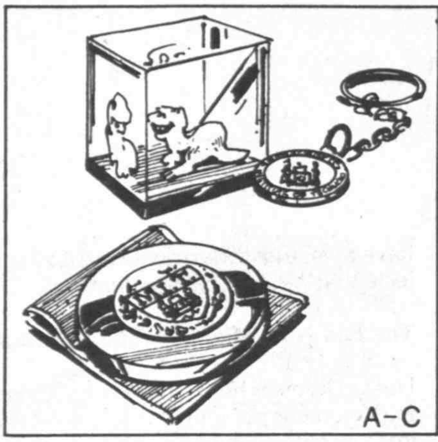
What is more, you probably do not even have to be a good writer to do this; after all, a "good" writer would not be caught dead outside the pages of the *New Yorker*. You need only be a better, or perhaps faster, writer than most engineers to get big bucks as an in-house writer at a major engineering firm. If, for instance, you took several engineering subjects while majoring in writing in Humanties, you would be in a great shape for a technical writing career.

Of course, Course XXI has a lot more to offer than writing. In fact, Course XXI covers many fields of interest such as History, Anthropology, Archaeology, Literature, and Women's Studies, and it is deservingly lauded for its outstanding professors and subjects in foreign languages and literatures. Course XXI is also for learning abstruse grammatical points such as why, contrary to popular belief, there is nothing wrong with splitting infinitives.

Go Ahead, Make My Day

Basically, in the words of Clint Eastwood, you have to ask yourself one question: Am I gonna major in VI, or not? The .44 Magnum Auto-Mag is, according to Clint, capable of removing the fingerprints from bodies. Your decision to major in Course VI could have an equally disastrous effect on M.I.T. As the overcrowding in Course VI strains the department every which way but loose, the quality of teaching and research in Course VI could well decline until the department is indistinguishable from similar departments in other universities. □

M.I.T. *Insignia*



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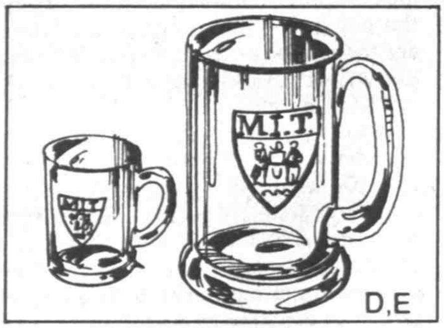

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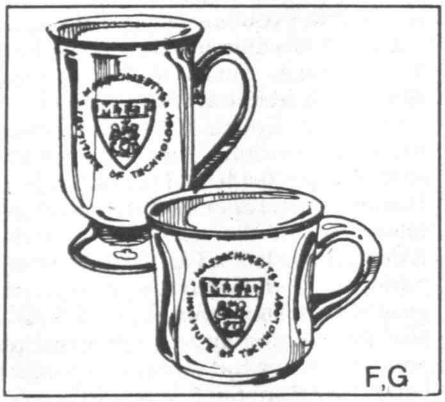

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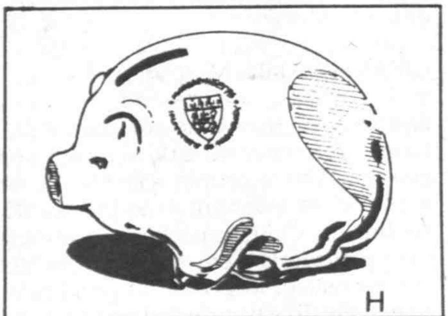

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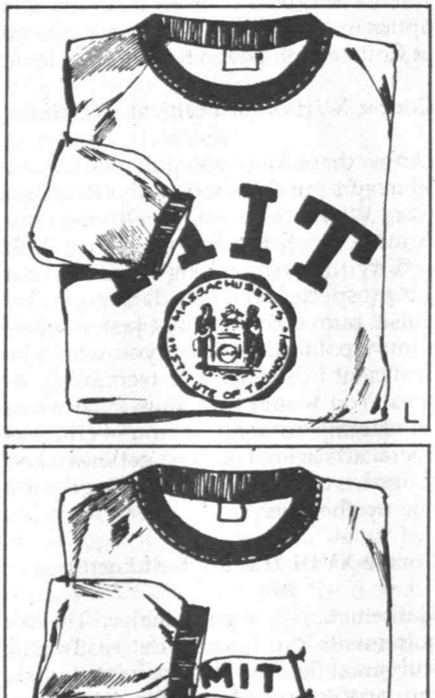

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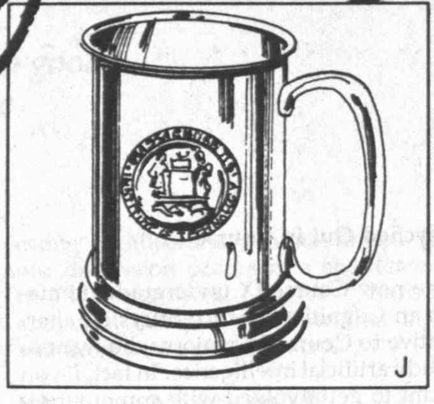

J

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Though the Books are Balanced, A Major Concern to Build Endowment

M.I.T. finished 1983-84 with a surplus of $805,000 on total operations of $658,611,000. It was a surplus with significance far greater than its size—"a source of considerable satisfaction after two years of shortfalls," say James J. Culliton, vice-president for financial operations, and Glenn P. Strehle, '58, treasurer, in their annual financial report.

M.I.T.'s expenses were higher by 12 percent in 1983-84 than in 1982-83, and operating revenues and funds to meet expenses were up 13 percent. The need for unrestricted revenues and funds to bring operations into balance was $6.7 million in 1983-84, down from $10.3 million in the previous year. But in an ideal world there would be no such need for unrestricted funds; they could be used to augment endowment.

It was a big year for gifts, grants, and bequests—a total of $49.1 million, just 2 percent less than in 1982-83, making the 1983-84 gifts the second largest total ever received in a single year. The figure is almost 45 percent more than that of just five years before.

But it was a lacklustre year for investments, the market value of M.I.T.'s holdings increasing by less than 1 percent to $771 million. Average interest rates were close to the previous year, say Culliton and Strehle, and dividend increases were "relatively modest."

Total funds of the Institute stood at $851.5 million at the end of 1983-84, up from $768.8 million a year earlier. Though the increase is significant, Culliton and Strehle are convinced that the endowment base is far smaller than it should be—hardly more than the total of one year's expenses.

They call for "a major effort to seek endowment to support and upgrade academic and research operations and to permit the creation of new programs. New endowment is also required to fund scholarships that make M.I.T. accessible to a diverse population and to compensate faculty and other staff at the level required to attract and retain those who provide an intellectually strong environment."

President Paul E. Gray, '54, shares this concern in his annual report for 1983-84. The Institute's endowment is presently "too small by a substantial margin," he writes (*see page A34*). "This capital base must be greatly expanded if we are to secure M.I.T.'s future as the premier science-based university."□

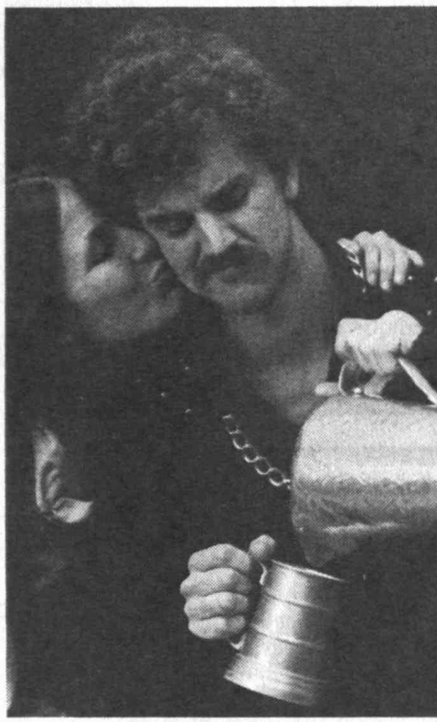
After five wins in eight games, the football club claimed fourth place and a berth in the play-offs of the National Collegiate Club Football League last fall. Manhattan College (above) was an early victim, 34-6. (Photo: James F. Butler, '85, from The Tech)

"Doc" on NOVA

"Edgerton's Incredible Seeing Machines" is the subject of NOVA during the week of January 14. Consult your Public Television station for local broadcast times.

BAMIT: More Blacks and More Visibility for Them

Blacks are society's undercapitalized, and they remain grossly underrepresented in such capital-intensive sectors as high technology. To



To mark its 10th year, the Shakespeare Ensemble will take Twelfth Night *on a first-ever California tour to Stanford, San Diego, and Los Angeles in January. Above: Andrea McGimsey, '87, and Andrew Borthwick-Leslie, '85. (Photo: Michael Pazin, '86)*

continued from page A17
change that is a continuing mission of both BAMIT (the Black Alumni of MIT) and the annual Black Students' Conferences on Science and Technology.

The 12th such conference attracted to the campus early last fall an audience of several hundred students, BAMIT members, and black activists—the latter including Marjorie P. Austin, compliance officer for the U.S. Department of Labor, Boston. Few blacks, said Ms. Austin, have yet attained jobs at the level of company decision-making, and the pressure on employers for equal opportunities for blacks is diminishing. Under the Reagan administration the frequency and depth of Labor Department audits have been reduced, and "five or six big companies have been added to the list of those we simply don't go to—where audits are a no-no," said Austin.

At their annual meeting in connection with the conference, BAMIT members urged that recruiting black faculty and administration be a top priority of the Institute's leadership. There simply are not enough blacks to serve as role models, not enough to make a visible presence, and BAMIT members pledged their help, says Ernest M. Cohen, '64. Cohen, who is treasurer of the organization, who had a major role in planning the two-day conference. □

Advanced Engineering

Five programs for professional engineers to study full-time at M.I.T. during the 1985 Spring Term have been announced by the Center for Advanced Engineering Study. There will be courses in design and manufacturing automation and control, systems reliability and risk analysis, and communications technology and policy. There will be opportunities for individualized advanced study in other topics and for partnership in ongoing M.I.T. research. Further information from Room 9-435, M.I.T., telephone (617) 253-6128. □

20 Years After the Green Building Cecil and Ida Rate Us Number One

Frank Press (left) president of the National Academy of Sciences, and Cecil H. Green, '23, were central figures at the celebration of the 20th anniversary of the Green Building.

Professor Emeritus Robert R. Shrock's diary records his first meeting with Cecil H. Green, '23, and his wife Ida in Chicago in 1950: "Nothing very definite came out of the matter."

That meeting came less than a year after Shrock had become acting head of the Department of Geology and Geophysics, which had just come perilously close to termination for lack of students and funds. Now Shrock was out looking for help wherever he could find it.

But there was chemistry between Shrock and Green after all, and they soon enough developed a summer program in which electrical engineering and geology students from M.I.T. and several other universities spent summers working for Green's Geophysical Services, Inc. (the predecessor company to Texas Instruments, Inc.). That program is generally credited with revolutionizing geophysical prospecting by introducing high-technology computer analysis.

Then one afternoon in March 1959 came an urgent call for Shrock: could he come at once to Dean George R. Harrison's office in the School of Science? It wasn't exactly what Shrock had planned for the rest of the afternoon, but it worked out all right: Shrock arrived in time to hear Cecil Green announce that "Ida and I want to give M.I.T. the funds for that building . . ."

Thus began the Green Building and the Center for Earth Sciences—and Cecil and Ida Green's record as major benefactors to the Institute.

Architect I.M. Pei, '40, first drew a 10-story building, but the meteorologists wanted to be up where they could measure the wind and use their radars, so Pei cut the building in two and stacked the two halves one atop the other, sketching what for M.I.T. was a veritable skyscraper with strong vertical lines and oval windows. When the ovals turned out to be impractical the windows became rectangles. But when Professor Harry G. Houghton, '27, then head of the Meteorology Department, sought a railing to protect his students using the roof, Aldo Cassudo, Pei's staff associate, was distraught at this proposed defile of the vertical motif. Houghton argued—successfully, as it turned out—that the rail would be small, almost invisible. To which, Houghton recalls, Cassudo replied in anguish, "Maybe you can't see the rail, but I will know it's there."

All this was just 20 years ago, recalled for a nostalgic audience brought together on October 2 to celebrate the Greens' landmark gift. And the next day began a major lecture series to celebrate the anniversary.

In that opening address, Frank Press, who was called from his Green Building office in 1976 to become President Jimmy Carter's science adviser and now heads the National Academy of Sciences, gave a powerful testament to the power of science and technology: "Advanced technology will become the core of agricultural, manufacturing, processing, and distribution," said Dr. Press. "Science and technology are our country's strongest card."

As the celebration ended with souvenirs given to the Greens by David S. Saxon, '41, chairman of the Corporation, Cecil recollected that when he graduated from M.I.T. "I kind of knocked my hands together and said, 'So long, factory!' But now I rate M.I.T. number one in sensitivity and regard for people's feelings." □

PHOTO: CALVIN CAMPBELL

NEWS FROM THE DEPARTMENTS

I
Civil Engineering

Dennis A. Fitzpatrick, S.M.'81, has been elected president and a director of Daniel O'Connell's Sons, Inc., Holyoke, Mass., a contracting firm that has many M.I.T. connections and number of contracts on the campus. Fitzpatrick joined O'Connell's in 1981; he succeeds **Robert F. Mahar,** '49, who had been president since 1972. Fitzpatrick will also serve as a director of the parent firm, O'Connell Enterprises, Inc. . . . . **Norman S. Kram,** S.M.'73, former vice-president of marketing of The Barkan Companies has been promoted to president of Barkan Construction Co., Inc., Chestnut Hill, Mass., with full responsibility for the firm's construction management and general contracting projects. Before joining Barkan, Kram was with United Engineers and Constructors, Inc.. . . **William E. Duvall,** S.M.'76, reports, "After four years as a resident construction engineer for Ralph M. Parsons Co. on the Northeast Corridor project, I have joined the Gilbane Building Co. in the Washington, D.C. area as a project manager." . . . **William A. Kakel,** S.M.'68, a lieutenant colonel in the U.S. Air Force, is currently attending the ten-month curriculum at the U.S. Army War College, Carlisle Barracks, Penn. The Army's senior school "prepares officers . . . for top-level command and staff positions."

II
Mechanical Engineering

Gordon Salmela, S.M.'74, writes that he has been "designing and building special structures and mechanisms for kinetic art, large magnetics, and radar antennas (and speedboats for recreation). Played on the successful M.I.T. volleyball club team until my marriage in 1979." . . . **Laurence G. Coffin,** S.M.'56, chief of the Technology Section, Fiber and Fabric Technology Branch at the U.S. Army Natick (Mass.) Research and Development Center, received a Certificate of Appreciation from the American Society for Testing Materials at the Society's annual awards dinner last October. Coffin was cited "for his tireless efforts serving numerous subcomittees and task groups of the Association over a 22-year period."

Thomas E. Willard, S.M.'83, is a member of the technical staff in the Digital Systems Physical Design Department at AT&T Bell Laboratories. . . . **Douglas Olson,** S.M.'79, a Ph.D. candidate in the department at M.I.T., has recently received the Owens Corning Research Award for work on data and design techniques for establishing comfortable and energy-efficient building systems.

William Kyros, S.M.'57, professor of engineering (specializing in mechanical and energy engineering) at the University of Lowell, Mass., was recently granted tenure. . . . **Jerry Sheldon,** S.M.'76, has accepted the position of director of marine engineering with the Analysis and Applied Research Division of Tracor, Inc., San Diego, Calif. Sheldon recently completed over 20 years of service with the U.S. Navy—his last assignment being director of ship silencing, Naval Sea Systems Command, Washington, D.C. . . . **Klaus M. Zwilsky,** Sc.D.'59, executive director of the National Materials Advisory Board, National Research Council, has been elected a trustee of the American Society for Metals.

Philippe Villers, S.M.'60, founder and president of Automax, Inc., was the featured speaker last October at the Cambridge Forum, a project of the First Parish (Unitarian) in Harvard Square. His topic: "The Robotics Revolution." . . . **Dana Yoeger,** Ph.D.'77, assistant scientist in the Deep Submergence Laboratory at the Woods Hole Oceanographic Institution, was speaker last fall at the first of the 1984 Natural History Series at the Mystic (Conn.) Marinelife Aquarium. Yoeger described JASON, a deep-ocean robot currently under development to perform a wide range of tasks at depths down to 6,000 feet.

III
Materials Science and Engineering

Professor **Julian Szekely,** and associate director of the M.I.T. Materials Processing Center, is editor of a recently-published 300-page volume, *Plasma Processing and Synthesis of Materials,* published by North Holland.

David N. French, Sc.D.'58, has announced the formation of David N. French, Inc., Metallurgists, Northborough, Mass., providing metallurgical consulting services to the utility industry and other users of boilers and steam generating equipment. . . . **David Colling,** Sc.D.'57, was promoted to associate professor of engineering, with tenure, at the University of Lowell, Mass. Colling is a registered professional engineer with specialization in industrial technology.

V
Chemistry

A major court victory late last fall for **Arthur S. Obermayer,** Ph.D.'56: the patent held by his Moleculon Research Corp., Cambridge, to protect its idea for a cube-type puzzle is valid, and CBS, Inc., and its subsidiary, Ideal Toy Corp., have infringed on that patent in their manufacture of various Rubik's cube products. Monetary damages remain to be determined by a second court action; Moleculon seeks $60 million plus a share of Ideal's profits from Rubik's cube and related sales.

VI
Electrical Engineering and Computer Science

The design and implementation of the computer systems environment to be created by Project Athena at M.I.T. is the responsibility of Professor **Jerome H. Saltzer,** '61, named late last year to be Athena's technical director. Athena is a $70 million program to apply personal computers to M.I.T. undergraduate education, and Saltzer has a major assignment, according to Professor **Steven R. Lerman,** '72: "the software needed to support the large network of high-performance work stations." Two major goals, said Lerman: "To minimize the differences students and faculty perceive when working on different computers from different manufacturers, and to develop uniform data representations for text, equations, graphs, and other forms of information that will be used to communicate across different computer types and programming languages." A member of the faculty since 1966, when he completed his Ph.D., Saltzer was one of the designers of the MULTICS operating system in the late 1960s.

Michael D. Scott, '67, who attended the UCLA

School of Law after graduating from the department, is now the author of *Computer Law* (New York: John Wiley & Sons, 1984, $75). Mr. Scott has an active practice in the field in Los Angeles, and he's considered an authority in the field. The book is described as "a thorough, up-to-date, and comprehensive discussion of the most important and most frequent legal problems in the computer industry."

Associate Professor **Jae S. Lim,** '74, won M.I.T.'s 1984 Harold E. Edgerton Award for "outstanding qualities of scholarship, teaching, and creativity among young, untenured faculty members." Since joining the faculty upon completing his doctorate, Lim has worked in many aspects of digital signal processing both at M.I.T. and at Lincoln Laboratory, and he's internationally recognized for work in speech enhancement. Lim was cited for "impressive productivity in research" and teaching "marked by clarity, enthusiasm, and sensitivity to students."

Claude E. Shannon, Ph.D.'40, Donner Professor of Science Emeritus, was one of five winners of the 1984-85 Who's Who in American Achievement Awards last fall. Cited for his contributions to information theory and computer technology, Shannon received a $10,000 prize from Marquis Who's Who, Inc.

The productivity of engineers is going down, says **Bernard M. Gordon,** '48, founding president of Analog Corp. In the early 1960s, he told Alan R. Earls of *Mass High Tech*, the rule of thumb was that one engineer could superintend the creation of about $1 million worth of product. Today the range is $600,000 to $1 million—and in the interim there's been an inflation factor of almost four times. "Partly because there is a perception of a shortage of engineers and partly because people think engineering is so complex that no single mind can encompass it," Gordon said, "employers are willing to load up on engineers. Yet they expect less from them." One result: many of today's engineers, says Gordon, are unwilling to take the kind of risks that are really necessary to succeed at their careers.

VI-A Program

Our summer material for the November/December issue had to be omitted as the copy deadline coincided with the rush of fall term registration.. Apologies to our many readers!

The annual West Coast VI-A picnic was held in Mitchell Park, Palo Alto, Calif., on Saturday, August 11, 1984. Approximately 45 Bay Area VI-A students and alumni enjoyed the food, Frisbee games, and good fellowship. Some of the alumni who attended: **J. Dana Chisholm,** '75; **Robert M. Colopy,** '74; **J. Payne Freret, Jr.,** '68 and wife **Lynn M. Roylance,** '72; **Alexander Holland,** '82; **Kenneth R. Knaus,** '78; **Juan C. Mercier,** '83; **H. DuBose Montgomery,** '71; **Joel E. Schindall,** '63, with wife and daughter; **Paul E. Stoft,** '49; and **Mark A. Troy,** '83.

Payne Freret and wife Lynn hosted a dinner at their Los Altos home for John Tucker the evening before the picnic. Included in the party were **Alan M. Marcum,** '78, and **Kenneth A. Van Bree,** '71. Alan now works for TZ Associates, Palo Alto; Ken is with H-P Labs, Palo Alto.

Envious of the great West Coast VI-A picnics, the VI-A students at AT&T Bell Laboratories and RCA in the New Jersey area inquired if they could start a similar affair. The first New Jersey area VI-A picnic was arranged for Thursday evening, August 9, at Johnson Park at Rutgers University and got off to a good start with about 15 attending. Next summer they hope to plan sooner in order to include a number of VI-A alumni from the Princeton area.

Cecil H. Green, '23, hosted his ninth annual TI VI-A luncheon at the Petroleum Club, downtown Dallas, on August 16. This is the first year that two VI-A faculty advisors to TI were able to attend—namely, Professor (Emeritus) **Truman S. Gray,** '29, and Professor **Carl E. Hewitt**. Professor Gray is advisor to the TI students in Houston and Professor Hewitt to the computer science (VI-3) students in Dallas.

While visiting the VI-A office last fall **Eric D. Black,** '77, helped set up the IBM PC/XT computer that the IBM Corp. has so kindly loaned us. His experience was appreciated. Eric is a principal member of the Technical Staff of Gould/Computer Systems Division, Campbell, Calif.

Eric W. Burger, '84, stopped by in late September and took Director Tucker to lunch. Eric had joined VALID Corp., San Jose, Calif. . . . At M.I.T. for the fall recruiting season, in charge of Hewlett-Packard Co.'s team, was **Richard W. Chin,** '80. Richard is development engineer/MTS at their Computer Systems Division, Cupertino, Calif. . . . On campus, too, for fall recruiting for Watkins-Johnson Co. was **James L. Fenton,** '78. Jim is head, Receiver Engineering Section, at W-J, San Jose. . . . **Mark T. Fuccio,** '80, tells us that he is now with Phoenix Data Systems, Santa Clara, Calif.

A nice note from **Aki Fujimura,** '81, thanks us for his "great" VI-A experience and says he has formed a new company—Tangent Systems Corp., Santa Clara—which is involved in CAD software design. . . . One afternoon **Holton E. Harris,** '44, was on campus to talk with Professor Myron Tribus, director, Center for Advanced Engineering Study, and stopped by to inquire about Professor (Emeritus) **Karl L. Wildes,** '22. Professor Wildes is now in the Carleton-Willard Village Nursing Home, Bedford, Mass. Karl was assistant in running Course VI-A when Professor William H. Timbie was director prior to World War II. It is also a pleasure to have Holton Harris' son, Walter, as a current junior in VI-A.

Steven T. Kirsh, '78, tells us he has formed his own company. . . . During a vacation trip back from Saudi Arabia, where he's a field engineer for an oil exploration team for ARAMCO and Schlumberger Corp., **Michael Moncavage,** '82, visited both Professor (Emeritus) Truman S. Gray, '29, who was his thesis advisor, and Mr. Tucker. He had some interesting experiences to relate about that area of the world. He expects to be back in the U.S. in about a year. . . . Also stopping by the VI-A Office in October was **James A. Roskind,** '79. Jim is with Harris Government Systems, Palm Bay, Fla.

Marshall G. Schachtman, '57, one of Mr. Tucker's earliest student aquaintances at the Institute, called one afternoon while attending a conference in Boston. Marshall continued with his VI-A employer, Bell Laboratories, and is now associated with AT&T Bell Communications Research following the AT&T divestiture. He is in contact with another early Tucker acquaintance, **Lester A. Gimpelson,** '57. Les has been with ITT many years and still resides in Brussels, Belgium, and—according to Schachtman—still has his first Mercedes 230 SL sportscar. . . . Another mid-October VI-A visitor was **Peter J. Waldo,** '81. Peter is with M/A-Com Linkabit, La Jolla, Calif.

I sadly report the death of **Jack E. Link,** '83, on October 29, 1984. Jack did his VI-A work at Hewlett-Packard Co.'s Medical Group, Waltham (Mass.) Division, where he was employed upon graduation. His medical instrumentation speciality with H-P involved him with doctors at Boston University's, University Hospital. It was while investigating an interference problem from a roof antenna at the hospital that he accidentally fell between two windowless buildings where he lay for five days before being found. Amongst other activities while at M.I.T., he was associate news editor of *The Tech*, and a member of TCA. Jack was buried in his hometown of Palatine, Ill.—John Tucker, Director, VI-A Program, M.I.T., Room 38-473, Cambridge, MA 02139

VII

Biology

Ronald D. G. McKay, a noted molecular neurobiologist at Cold Spring Harbor Laboratory, has joined the department at M.I.T. as the first Edward J. Poitras Associate Professor in Human Biology and Experimental Medicine. McKay, a native of Scotland who studied at the University of Edinburgh before coming to the U.S. in 1978, holds his M.I.T. appointment jointly with the Whitaker College of Health Sciences, Technology and Management; his work is in molecular approaches to the study of the central nervous system. The Poitras professorship is the result of a gift of the late **Edward J. Poitras,** '28, an engineer, inventor, and philanthropist who was associated with Fenwal, Inc., and its parent firm, Walter Kidde, Inc.

Frederick Ausubel, Ph.D.'72, professor of genetics at Harvard Medical School, presented the 1984 Sterling B. Hendricks Memorial Lecture before the American Chemical Society at its annual meeting last August in Philadelphia, Penn., sponsored by the U.S. Department of Agriculture's Agricultural Research Service. Asubel's topic: "Biological Nitrogen Fixation: Recent Advances and Future Prospects."

Marie (Fortunati) Gately, M.P.H.'41, former director for the Division of Health Education of the Massachusetts Department of Public Health (1960-69), passed away in Melrose, Mass., on June 5, 1984. Gately taught public school for one year before beginning her career in public health—developing the first health education program for the Boston Catholic Archdiocese and directing and supervising numerous public health committee programs throughout the state. A strong advocate of a screening program for tuberculosis control after World War II and prime mover in immunization with the Salk vaccine, Gately was also active in promoting flouridation of water in the prevention of dental caries.

XIII

Ocean Engineering

Judith T. Kildow, associate professor of ocean policy at M.I.T., has been appointed for a one-year term (ending July 1, 1986) by President Ronald Reagan to the National Advisory Committee on the Oceans and Atmosphere. She would have been a colleague of Anne M. Burford on that committee but for Ms. Burford's forced resignation last summer.

Clark Graham, Ph.D.'69, (Captain, USN), was appointed professor in the department at M.I.T. last July 1, and he is now head of the Naval Construction and Engineering Program (Course XIII-A). Graham is credited with developing a new field—comparative naval architecture—in the early 1970s. Most recently, Graham was technical advisor of the U.S. Navy's DDG51 Program, replacing Professor **David V. Burke, Jr.,** Ph.D.'72 (Captain, USN), who retired from the navy and resigned from the M.I.T. faculty in June 1984. He has accepted a staff position at the Charles Stark Draper Laboratory, Cambridge. . . . **W. David Whiddon,** '76, (commander, USN), was appointed associate professor on July 1, 1984, serving as academic officer of Course XIII-A, replacing Associate Professor **Terrence Tinkel,** '78 (commander, USN), who retired from the navy and the faculty in June 1984.

Professor **Robert J. Van Houten,** Ph.D.'76, resigned from the faculty at M.I.T. in June 1984, to accept a position at Air Flow Research, Inc., Watertown, Mass. . . . The IEEE Council on Oceanic Engineering honored Professor **Ira Dyer,** '49, with the IEEE/COE Distinguished Technical Contribution Award on September 22, 1984, for his contributions to ocean acoustics and his leadership in ocean engineering education. . . . Professor **A. Douglas Carmichael** has been elected vice-chairman of the New England Section of the Society of Naval Architects and Marine Engineers. . . . Professor **Koichi Masubuchi** is vice-president of the Japan Society of Boston and vice-chairman of Commission X of the International Institute of Welding (IIW); he was chairman of the U.S. Organizing Committee of the Annual Assembly of the IIW, which was held in Boston last July.

Associate Professor **Peter N. Mikhalevsky,** Ph.D.'79, received the A.B. Wood Prize and

NEWS FROM YOUR CLASSMATES

14

Levi B. Duff wrote in August from his home in Pittsburgh: "I am sorry that I was unable to attend the reunion and am glad you all enjoyed it. There is nothing new with me except that on the annual checkup, the doctor earlier this month had taken a cardiogram and said that my heart was in fine shape. He also suggested that I use a cane when walking any distance. This is because my old legs are getting more wobbly as time goes on."

Since **Clifford L. Muzzey** left Lexington in 1980, where he had lived for 94 years, he had made his home with the Reverend Martin J. Bagay, a graduate of the Episcopal Divinity School in Cambridge. Their home is now in Sandusky, Ohio. Reverend Bagay wrote last August of Cliff: "He continues to astound his physicians, who find that they can write him nothing but a clean bill of health. In fact, his present M.D., convinced of his remarkable condition at 97 (he will be 98 on December 11) has exclaimed, 'Cliff, you can eat anything you want!' " Cliff has two M.I.T. sons, Clifford L. Muzzey, Jr., '41, and Benjamin C. Muzzey, '43.

James B. Reber, our class estate secretary wrote on September 19 from his home in Auburn, N.Y., that it was later than he thought when he returned there, so that he wasn't able to come to our June reunion. He went on to say, "I have had a busy and delightful summer here in Auburn. Most members of my family have visited me at various times, from a few days to two weeks—my children, grandchildren, and great grandchildren—from Johnstown, (Pa.), Pittsburgh, Baltimore, and Houston. Each year we have what's called the Reber golf tournament at the Country Club, with a trophy and family dinner. I can't win it any more; they are all too good. This Friday, my daughter and her husband will come to Auburn to help me pack and close my house for the winter. I will follow them back to Johnstown in my car and stay there until after Christmas, when my son and I will drive to Florida." Jim's winter address will be: Errol by the Sea, Condo 320, 4501 S. Atlantic Ave., New Smyrna Beach, FL 32069.—**Charles H. Chatfield,** Secretary, 177 Steele Rd., West Hartford, CT 06119

15 70th Reunion

In the cold of the winter, everything seems to be "quiet." However, I had a letter from **Francis Hann** a while ago. He gave me some tidings of himself, and sent a lot of clippings and jokes—the kind of a fellow we like to have among our acquaintances! . . . **Joseph Woodward Barnwell**'s daughter writes, advising that her father passed away; he was very "special" and will be missed. She mentions that he was an ATO at M.I.T. and had many fond memories of life at the ATO House on Newbury St. He worked with duPont in Virginia before serving on the Mexican border in the summer of 1916 with Company A of the S.C. Engineers. He served as state bridge engineer for the highway department and then operated Barnwell Bridge Construction from 1935 until 1972, building bridges over many streams and rivers in South Carolina.

I asked **Loring Hall** for more of his diary notes, and he comes through with the following:

May 28, 1913: Had our final English exam today. It seemed unfairly stiff. Wrote my opinion of it in plain words at the end. Ordered 500 sheets of fine writing paper from Herman Flister, Jr. (price $1.25). Dick Hefler and I went to the office of the Eastern Steamship Co. to see what arrangements we could make for getting to the M.I.T. summer surveying camp in August, by boat.

May 31, 1913: Final physics exam from 9 to 12. It was a sticker!

June 2, 1913: The precision exam today was supposed to be from 2 to 4, but it was so tough no one could finish it.

June 6, 1913: Final in Math 31 from 9 to 12. Not bad. Think I passed. Went in town for a haircut, but found the barbers were out on strike. The janitor said, "The union got Tom."

June 7, 1913: Sold aluminum cooking utensils in Brockton, Mass. and made about $400 in commissions toward my M.I.T. expenses.

August 4, 1913: Took the steamer *Governor Cobb* for Eastport, Me. on the way to M.I.T. summer camp. On board were **Hefler**, **Highley**, **Scully**, **Daniels**, **Wardwell**, **Hyneman**, **Connor**, **Shields**, **Chellman**, and **Rooney**. Shared stateroom 151 with **Highley**. Had a fine sail to Portland, where five other 1915 men got on board. Had a fine time singing on deck until bed time. No one was seasick.

August 15, 1913: Got up at 4 a.m. and saw the sun rise before getting to Eastport. Took the train there for Ayers Junction, where we transferred to the Washington County train for E. Machias. It was a bumpy ride. From E. Machias we were transported to Gardner Lake in a two-horse "barge" with very stiff springs. **Wardwell** and I were assigned to tent 1 in Row A, so we are labelling our abode "A-1." Picked blueberries almost as large as cherries, right at our door. Great place!

August 16, 1913: Reveille sounded at 6:30, but I was up and in the lake before that. The water was cold and very refreshing. Started work at 7:45 on the subject of stream-gauging. Then took the motor boat across the lake to Chase's Mills, where 12 of us, under Professor Howard's direction, repaired our triangulation signal that had been damaged by winter storms. I think this eight-week summer school course is going to be the highlight of the whole four years!

As always, thanks, Loring, and come on '15ers, let's have some news from everyone! Have to keep our '15 column so interesting that it will continue to be a highlight in the *Review*. Many comments in recent months from other folks besides the Class Supreme indicate that others are very much enjoying our column. This time of the year I need to have your news to keep up my spirits on these cold winter days and evenings!—**Joyce E. Brado**, Secretary and Class Agent, 491 Davison Rd., Apt. 9, Lockport, NY 14094

16

We're pleased to know that **Charlie Reed** is feeling much better. He writes, "I had planned a reunion visit for June, but a heart attack broke that up. My children arranged a large celebration for my 90th birthday on May 12. I succeeded in getting Lansing Warren to come from California for it, and I had planned to bring him to the reunion in June. However, both he and I had health problems, so he returned to California and I flew up to our summer home in Wayne, Maine. On July 16 I went to the Kennebunk Valley Hospital in Augusta for treatment after a slight heart attack. I returned to Wayne and spent the summer doing very little till I was pronounced able to fly back to Silver Spring on September 14. I checked in at the navy hospital in Bethesda and was told to continue taking inderal for three more months. I feel great and have just today caught up with my correspondence and bills.

"Your idea of another reunion appeals to Mil and me but I am stuck here for the winter. We enjoy the reunions. At my 90th I had a letter from Nancy and Ronald and from the president of M.I.T., from the selectmen of the Town of Weymouth, Mass. and one from the South Shore Hospital in South Weymouth. The latter was my birth place. My best wishes to all the classmates, and Mil joins me in happy remembrances of many reunions."

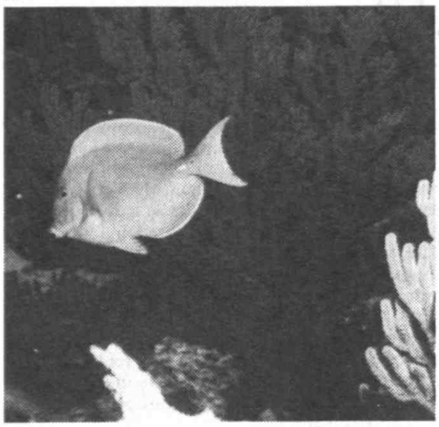
We're also happy to know of the substantial improvement of his wife, Grace, as noted in **Dan Comiskey**'s recent letter: "It was pleasant to see you and Sibyl and the classmates and relations. Grace was so sorry not to be with us. However, she is making good progress in walking again. Thanks to you and Sibyl for your good wishes and the flowers to top it." . . . In mid-October, **Barney Gordon**'s sons, Malcolm and Gene, were honoring their father on his 90th birthday at a special dinner at the Ritz-Carlton Hotel in Boston. Many family members and friends were invited. We'll write more about this in the next column since this is being written before the happy event took place. . . . In mid-July, we had a call from the son of **Milton "Mickey" Schur**, who said that for health reasons Mickey would not be able to attend our 68th reunion luncheon. In recent years Mickey had been attending our reunions regularly, and we had come to know him as a truly interesting, knowledgable, talented, wise, kind, and gentle person. In late August his son called again to tell us that Mickey had died in July. We're grateful for the privilege and pleasure of having shared a part of his life.

Keep the letters coming so that our column will continue. Keep eating, drinking, walking, breathing—everything in moderation, and of course write to us.—**Bob O'Brien**, Acting Secretary, H.E. Fletcher Co., Groton Rd., W. Chelmsford, MA

18

As far as class notes are concerned, we are at a very low point. I would appreciate any items you

1.



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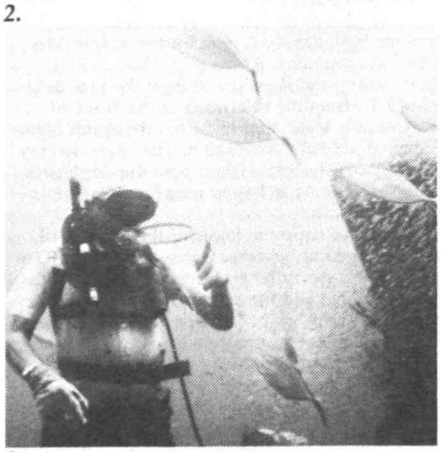

3.

1. Photographer Frank Rickers, '22, sets out to sea. In 20 years of underwater work Rickers has produced thousands of photographs like this one of a Caribbean Tang (2), which he shows to school groups, clubs, and community organizations. "The beauty and excitement of underwater life is hard to match," says Rickers, who earned his SCUBA certification at the age of 73. Now at 83 he has snorkled and dived at far away spots all over the world but claims the very best spots are off the coast of Florida and in the Caribbean. 3. Rickers at wreck site.

could send me.

You will recall the mini reunions we enjoyed after our 50th reunion at Endicott House. As our numbers decreased, we were joined by other classes having the same problems. Finally, the Cardinal and Grey Society was organized—including all alumni who have celebrated their 50th reunion. For the past three years we have had Sunday meetings in the fall and spring—a most enjoyable time for a get-together at the beautiful Endicott estate—with a talk by a senior M.I.T. faculty member. The attendance—over 100 members—is most satisfactory. The October 21 meeting featured Professor Emilio Bizzi, director of the Whittaker College at M.I.T. Selma and I represented 1918 and were joined by Hazel Fletcher who came from Greenfield, N.H. for the event.

We had a nice visit over the phone from Eleanor Kilduff who is enjoying the cool breezes in Rye, N.H. before going to her winter home in Sarasota, Fla. in November.

We were happy to receive a warm and breezy letter from Elizabeth Howe, who is now living in Fall River, Mass.—**Max Seltzer,** Secretary, 1443 Beacon St., Brookline, MA 02146; **Leonard I. Levine,** Assistant Secretary, 519 Washington St., Brookline, MA 02146

19

Receiving no new material from our class, we record for you some of the spirit and pathos of our 65th reunion, quoting from recent communications. The Alumni Association did a great job for all the reunions, and to do a better job next time, they sought our advice. We suggested earlier solicitations for the various activities and that they get tickets in our hands before leaving for the ceremonies.

Doc Flynn, a member of our reunion committee had definite plans to be with us, but problems arose that prevented his attendance. We missed him and his good wife. Such problems arose with others such as **Aubrey P. Ames** who writes, "As it turned out I would not have been able to attend in any case. I was hospitalized by a mild heart attack for four days and under strict medical supervision for a month. Am just now getting back to normal but only three months short of my 90th birthday." . . . Suzan B. Gallagher, daughter of **Pierre Blouke,** writes, "My father asked me to write to say how sorry he was not to be able to attend the reunion, but he was at the time in the hospital for a cataract operation." . . . **Louis J. Grayson,** after an initial heart operation writes, "The doctors concluded they had inserted the wrong kind of pacemaker, and that meant they had to install another kind."

Oscar de Lima, who attended the reunion with his wife Sue, writes, "It certainly was a bang-up GREAT reunion." . . . A letter from **Alan McIntosh,** who left on another trip just after the reunion, promises some pictures later. . . . **John Riegel** writes, "I was lucky to be one of the nine who were at our 65th reunion." . . . Mrs. **Chester C. Stewart** writes, "This is to let you know that my husband died on May 18, 1984. Right up to the end, he was looking forward to joining his class this year." . . . **William H. Vogt, Jr.,** writes, "Yes, I had a wonderful time at our reunion." . . . And a card from **Francis Weiskettle** says, "I am to some extent tired and worn out from the *S.S. Norway* cruise in April and the three-week South Africa trip in May."

Please note that in the October issue of the *Review* we are honored with a picture of the nine classmates who attended our 65th reunion. Please write me about yourself.—**W.O. Langille,** Secretary, Box 144, Gladstone, NJ 07934, (201) 234-0690

21

Happy New Year! May 1985 treat you kindly!

A letter from Assistant Secretary **Sam Lunden** reported that he and Leila spent the summer in South Dennis as usual. They attended the annual picnic of the M.I.T. Club of Cape Cod at the Waquoit Bay Yacht Club in Falmouth on August 29. Classmates **Whitney Wetherall** and **Don McGuire** also attended. Everybody brought their own cuisine specialty, and the club provided large kettles of wonderful clam chowder. Sam is a member of both the M.I.T. Club of Southern California and the Cape Cod club.

Assistant Secretary **Josh Crosby** wrote me late in the summer from their cottage in Brooklin, Maine. Said he, "We had a nice summer and will be going home to Sarasota in another week. We saw little of Millie and **Herb Kaufmann** last spring as they had a lot of family visiting them." A follow-up letter from Josh's wife Claudia in late September told of Josh having a series of small strokes on the way home and landing in the hospital and subsequently in the Sarasota Nursing Pavilion. In a phone call to Claudia, I learned that no paralysis is involved, and she expected Josh to come home soon. The Crosbys celebrated their 50th wedding anniversary in July. They are a fine couple.

A good letter from Class President **Carole Clarke** came in a few days ago and was most welcome. He tells me his Jersey coast neighbor, **Munroe Hawes,** wants to sign up for our 65th reunion. Cac says that every few months he gets a phone call from **Ed Farrand** in La Jolla, Calif. Ed's eyes are not good, and he needs secretarial help to carry on. Plans for a very substantial class gift in 1986 are under way, and it is believed that the five-year giving and bequests will exceed $2 million. Our next reunion is now only a year and a-half, away and we're hoping for a good turnout.

Class Vice-President **Bob Miller** writes that he returned in late September from a two-week visit with his daughter Jo who recently moved from Cape Cod to Orange, Va. Orange is about 100 miles from where Bob lives in Silver Spring, Md. Bob still feels the tremendous void from the loss of his dear wife Helen last February. "It was the most tragic event of our lives. We all miss her terribly, and she remains constantly in our thoughts and conversation. Her warm friendly personality appealed to everyone she met." Bob's letter also included the story of the honeymoon trip he and Helen took around the world, using money he had saved for years for just that purpose. It is a wonderful story and extracts will be included in the next issue of the *Review*. It deserves to be printed in full.

Your secretary and his dearly beloved recently celebrated (October 1) their 60th wedding anniversary. It is sad that she and I have to be separated but her Alzheimer's disease has made it necessary that she be in a nursing home. It is six miles from where I live, and I see her almost every day. She recently was in the hospital five days with pneumonia, but antibiotics cleared it up quickly. Your secretary still hikes and recently spent a weekend with his daughter's family in the Adirondacks, hiking, and canoeing.—**Sumner Hayward,** Secretary, Wellspring House E64, Wash. Ave. Ext., Albany, NY 12203; **Josiah D. Crosby,** Assisant Secretary, 3310 Sheffield Cir., Sarasota, FL 33579; **Samuel E. Lunden,** Assistant Secretary, 1149 S. Broadway, Suite B-800, Los Angeles, CA 90015

22

Ruth and **Milt Manshel** spent several weeks in the lake country of northern Italy and Switzerland in August and September, avoiding the heat and humidity of West Palm Beach. . . . Vickie and **Ed Merrill** moved in late June to St. Simeon's Episcopal Home in Tulsa, Okla. The Merrills write, "On June 18, disaster struck, in the person of an uninsured van driver who ran a stop sign at a speed which was sufficient to knock our 1968 Cougar across a four-lane avenue, head-on into a light pole. Fortunately, Ed was driving alone—no one in the front passenger seat would have survived. The car was 'totaled,' and Ed went in an ambul-

ance to the hospital, where he spent two nights with a fractured left wrist, broken cheekbone, and lacerations of the face and nose that required plastic surgery." In spite of this trouble, Ed and Vickie were able to move to their new quarters ten days later. By September, they had settled in, and Ed had substantially recovered from the accident.

The August, 1984, issue of *The Mayflower Quarterly* includes a fine picture from 1967 of **Norman J. Greene**, signing his name in a rare book, "Confutation of the Rhemists," the property of the Western Reserve Historical Society in Cleveland. This book, secretly printed in Leyden in 1618, is of particular interest to descendants of the Mayflower passengers. In 1967, Norm was governor-general of the Society of Mayflower Descendants; each newly elected governor-general signs the blank page in front of the book.

Harold A. Connor, a long-time resident of North Andover, Mass., died August 21, 1984, at the Anlaw Nursing Home in Salem, N.H. After M.I.T., he received a master's degree in education from Salem State College, after which he taught at public schools in Exeter, N.H., and Saugus and Peabody, Mass. Thereafter, until retirement, he was employed as a chemical engineer by the Shell Oil Co. He was a Navy veteran of World War I. He is survived by his wife, Grace (Foley), a son, two daughters, and seven grandchildren. Our regrets are extended to his family.—**Yardley Chittick**, Secretary, Box 390, Ossipee, NH 03864

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Mary and **Royal Sterling** have a new permanent address beginning November 1: Miramar II, Apt. 303, 9960 AIA South, Jensen Beach, FL 33457. They made a visit to Isabelle Skinner in Waban in September. Royal suggests the possibility of a class meeting next June in Cambridge during the alumni events, either at a local hotel or at one of the dormitories; aside from visiting, we could discuss our 65th reunion and perhaps elect a few honorary members. A principal question about our 65th is whether to go to the Cape again or some other distant place or to stay in or near Cambridge in a local hotel or McCormick Hall. Please write to Royal and tell him whether you would come to such a meeting in June, and give him or **Gerry Fitzgerald** any ideas you may have about our 65th, which could be our last. Isabell Hokannson, wife of **Wolcott Hokannson** (our only living honorary member), died on September 5, 1984.—**Richard H. Frazier**, Secretary/Treasurer, 7 Summit Ave., Winchester, MA 01890

24

As your scribe has been overly occupied by maintenance problems on his church and condominium, these notes will be somewhat hodge-podge items. The snows of January should make this fireside reading even for those absorbing balmy Florida air. I have just talked with Rene, wife of **Ed Moll** in Old Lyme, Conn., and learned that he did not feel like battling the confusion of our 60th, choosing to enjoy his new home, near his son Dick, an executive with the Electric Boat Co., submarine manufacturers.

We have a note from Robert C. Fuller, son of **Percy D. Fuller,** saying that he passed away January 23. 1984. He was an ocean engineer, who studied naval architecture. We are advised by an unknown writer that Lieutenant Colonel **Gordon H. Crabb** (retired) died in Winter Park, Fla. on August 1, 1984. He was awarded an S.B. and S.M. in electrical engineering and circa 1949 was a mechanical engineer with an office in the Panama Canal Zone.

Norman L. Marden died July 11, 1984 in Quincy, Mass. He earned his S.B. in chemical engineering. He applied his technical knowledge to several fields, becoming New England sales manager for American Laundry Machinery Co., retiring in 1979 as an engineering consultant.

Rock Hereford writes that he enjoyed **Don Moore**'s letter summarizing the 60th activities and has his book in the last stages, but keeps the title secret. . . . Incidentally, **Dick Shea** has published a thin small book of essays about practically everything including "Engineers Are Human, Too (sometimes)," "Fore!" and "Double Six Spades." It is dedicated to his departed wife, Helen.

There has been some correspondence with Mrs. Frances A. Houston, widow of **Holland A. Houston,** who writes that her estate has been willed to M.I.T. We are very grateful for this action.

Rarely do we hear of two 'mates, simultaneously, in different parts of the country, undergoing personal repairs, but **Roland Black** and **Frank Manley** opened cases of shingles just before our 60th. To us engineers, that stress is known as "Herpes zoster," and it is painful! Glad that you have recovered, men.

Frank Billings rarely faces law enforcement men, but at our Friday night banquet, he was very happy to face two campus police officers, who had retrieved his mislaid glasses with special hearing aids. Therefore, he was able to see and hear our program. . . . **Dick Shea** has been awarded a centennial medal by the IEEE, in the nuclear and plasma division. He joins **Herb Stewart** and **Joe Lusignan** with that honor. . . . Requests for the small photographs and directories of the 60th reunion have been scarce.—Co-secretaries: **Russ Ambach,** 216 St. Paul St., Brookline, MA 02146; **Dick Shea,** 709 Cypress Pl., Sun City Center, FL 33570

25 60th Reunion

There were thousands of visitors to Cape Cod the past summer. Among them was **Milt Salzman,** who has a granddaughter in Barnstable. She is a shellfish warden and mate on a fishing boat occasionally. While on the Cape, Milt came to Chatham, and we had an enjoyable visit with him. Of course the reunion was discussed, and Milt had some fine suggestions which have been passed on to **Jim Howard**.

Arch Nickerson called to learn who had provided the article which appeared in the August/September 1984 issue of the *Review*. Arch had been interviewed by a reporter from the Quincy, Mass. *Patriot Ledger*. The article regarding his banjo clock was discovered by a member of the *Review* staff. Hope all of you saw the picture and the article.

A letter from **Kamy Kametani,** dated August 22, 1984, mentions that Japan was covered by heavy snow for about 29 days in January and February. However, when he wrote the weather was hot. Kamy wanted to be sure the class notes mentioned his meeting with my son Dick in Tokyo. Class notes are prepared nearly two and one-half months before they reach classmates in the United States. Another three months later Kamy receives his copy, and the May/June issue (which mentioned his son) had not reached him in August.

The M.I.T. Club of Cape Cod held its annual picnic at the Waquoit Bay Yacht Club in August. **William Stone,** who lives in West Dennis, was the only other classmate in attendance. . . . A letter from **Bill Asbury** brought the sad news of the passing of **Eugene Herman** on August 20, 1984 at the Cranford Health and Extended Care Center in Westfield, N.J. Gene had a serious stroke about a year ago and had been in hospitals and nursing homes since. Gene was one of a group of 15 chemical engineers recruited by Professor Warren K. Lewis in 1927 to go with Standard Oil Development Co., in Baton Rouge to explore methods of producing oil from coal. None of the group had experience in the oil industry and were referred to as "the 15 virgins." **Bill Asbury** and **Marion Boyer** were in the group. Gene continued with the company, which became Exxon Research and Engineering until he retired in 1965. Gene attended many of our reunions and was planning for the 60th. He was a member of the Civil Defense Corps during World War II, served as deacon in the Westfield Presbyterian Church, and held memberships in the Echo Lake Country Club, the Westfield Old Guard, the Red Cross, and the M.I.T. **Alumni Association**. He is survived by his wife, Gertrude, two sons (Gene Jr. and Chris), and six grandchildren.

A letter from Herbert Sontag, Jr., '50, brings word that his dad **Herbert P. Sontag** died on August 18, 1984 as the result of injuries from an auto accident that occurred three weeks earlier. Since retirement, the Sontags have been living in St. Petersburg, Fla. Herb was head of engineering for the Firth Carpet Co, where he was responsible for several of their plant expansions in the south and in Puerto Rico before Mohasco acquired Firth. He was a registered engineer in New York State. Both Herb, Jr. and his brother Don, '52, graduated from the Institute as the result of their father's encouragement and influence. Herb is survived by his wife Gertrude.—**F. Leroy (Doc) Foster,** Secretary, 434 Old Comers Rd., P.O. Box 331, North Chatham, MA 02650

26

For the first time since graduation in 1926, **Juan T. Villanueva** returned to visit this country. Juan is a mechanical and electric engineer and consulting textile engineer in Guinobatan, Albay, Republic of the Philippines. We met him and his charming wife at the Hilton in Boston, and proceeded to tour the area. Imagine the transformation in nearly 60 years; most striking was the expansion of M.I.T. Juan told us of the Japanese occupation of the Islands during which they were stripped of all their possessions, the re-occupation, and the recent developments under the current harsh regime. Nevertheless, they have survived well and are enjoying their eight grandchildren, children of their only son, who died a few years ago. I hope Juan will write a letter describing his experiences for these notes.

Pink Salmon recently wrote **Arthur Fuller**: "Between Maine, the Cape and a few other places in Eastern New England, this is the first chance I've been home long enough to write. I finally retired in the spring of 1980, and moved to this life-care community in the summer. Our set-up, built around 1979, is well designed and comfortable, the food is good, and medical facilities, both in-house and with a hospital across the street, are also good. We are 25-plus miles from Philadelphia and Princeton and about 65 miles from downtown Manhattan, so we are not completely isolated. Except for structural patching up here and there, Mary and I are enjoying good health and we hope you are also." . . . **Arthur Fuller** replied: "My daughter, three sons and nine grandchildren are doing fine. My oldest son is a major in the Air Force and Liaison Officer to the civilians at the Lawrence Radiation Laboratories, Livermore, Calif. My next oldest son is zoning administrator of Shreveport, La., and my youngest son is a bartender at Harrah's in Lake Tahoe. Fortunately for me, the Navy Hospital keeps me in good shape with regards to my Hypertension and Diabetes by means of six-monthly EKG and check-ups and 17 pills daily. My wife died in 1982, aged 72. I'm 81 years old and still drive everywhere." . . . Added to the myriads of honors awarded to **Stark Draper** in May, 1984, was that of Doctor of Science, bestowed on him by Boston University.

From the Bridgeport, Conn., *Post*, news of the death of **Robert A. Nisbet** on July 21 was noted. He is survived by his wife, Mary Patrick, and a sister, Mrs. Andrina Prangley. Bob was 82 years old. He was with the General Electric Company for 41 years; he lived in Stratford, Conn. for 34 years where he had been past master of the Charles W. Mead Lodge. . . . From his daughter, notice has been received of the death on July 20, 1984, of **Willard F. McCornack** of 6905 Lois Drive, Springfield, Va.—**William Meehan**, Secretary, 191 Dorset Rd., Waban, MA 02168

David S. Saxon, '41 (right), chairman of the M.I.T. Corporation, presents to James R. Killian, Jr., '26, a resolution praising "his magnificent example of service and dedication, which extends over half of M.I.T.'s total history." (Photo: Calvin Campbell)

27

Arthur J. Connell died on August 26, 1984 at the Fairlawn Nursing Home in Lexington after a long illness. Born in Springfield, Mass., he was a good friend of classmates from the same high school: **Bud Fisher, Dick Cheney, Fred Geary,** and **Gordon Calderwood**. Gordon writes of Arthur: "A loyal alumnus, avid tennis player and golfer, Art possessed a keen wit and a modest but confident bearing. His passing though it brought relief, will bring sadness to many friends."

Art became a vice-president and director of E.B. Badger and Sons. When the firm merged with Stone and Webster in 1951, he became vice-president of engineering and manager and director of that firm in 1962. He retired in 1970. In the sixties he participated in conferences here and abroad on the problem of world oil supplies and the energy crisis. He was active in the design and operation of petroleum refining and petro-chemical plants. During World War II, he was involved with the first catalytic cracking plants for the production of aviation gasoline, synthetic rubber, and other strategic materials.

Art was a member of the American Chemical Society, Institute of Chemical Engineers, Society of Chemical Industries, American Petroleum Institute, and Alpha Chi Sigma. He attended alumni day luncheons regularly when he was well. A modest soft spoken fellow, we shall miss his witty companionship.

William G. Payne died on June 23, 1984 in Troy, Ohio. He was a long-time patient at the Kettering Convalescent Center in Kettering, Ohio. . . . **Robert N.C. Hessel** died on June 20, 1984 in Worcester. He gave 40 years of service with the U.S. Steel Corp. in Worcester.—**Joseph C. Burley,** Secretary, Box 416, RFD No. 3, Epping, NH 03042; **Lawrence B. Grew,** Assistant Secretary, 21 Yowago Ave., Branford, CT 06405; **Prentiss I. Cole,** Assistant Secretary, 2150 Webster St., Palo Alto, CA 94301

28

It is always difficult for a class secretary, with any degree of modesty, to write in the first person. This time, however, it can hardly be avoided. September was a month to remember for the Smiths! Walter became 80 years of age, and Florence conjured up a party that saw 160 relatives and friends filling the local church hall. We were delighted that some of our classmates could be there to help in the celebration. They were: Frannie and **Jim Donovan**, Gladys and **Dave Olken**, Anne and **George Palo**, Dorothy and **Herm Swartz**, Ruth and **Abe Woolf**. It was mostly a rather mature group who brought together for happy reminiscence many who had not met for a long time.

Then there was the M.I.T. National Alumni Conference in Toronto, Canada where we (the Smiths, again) were invited and presented, jointly, with the 1984 Bronze Beaver Award at the awards luncheon. Also present there for the class were the Donovans and our honorary member, **Shirley Picardi**. The beaver award is a very great honor, and the occasion was one that we will remember (hopefully) for a very long time. We know that much of the credit is due to the spirit and loyalty of our class. The award citation contains this statement: "If one were to select a focal point of their activity, it would be the Class of 1928. This class has consistently outperformed all other undergraduate classes in participation in the Alumni Fund." We can only express our deep appreciation to the class and to the Alumni Association.

The 1984 Bronze Beaver to Florence and Walter Smith, '28, from Mary Frances Wagley, '47 (left), president of the M.I.T. Alumni Association, for some 50 years service to M.I.T. Walter has served for the past 15 years as class secretary, was 50th reunion chairman, and participated in two major capital campaigns. Florence, as an honorary alumna, has been active in the Alumni Council and as a telethon solicitor. They are currently jointly serving as chair of the Cardinal and Gray Society. This unprecendented joint award recognizes that Florence and Walter have been inseparable in their wide-ranging involvement. (Photo: Mario Scattoloni)

We have a note from **George Chatfield** enclosing a copy of his letter to the Chatfield family. The letter, a bit of history, is an account of his last trip, as a student, from his home in Minneapolis to M.I.T. in the fall of 1927. Here is the story in his own words: "R.R. fare and expenses in those days totaled about $70 one way. To my Dad I said, 'I can *buy* a car and drive to Boston (1,400 miles) for less than $70. Finallly, I got his okay. Then a 1914 Ford cost $35 but had no lights or battery. For $10 I got a new top and two tires. Dad and I rebushed the front end. Dad said, 'If the back end goes, you'll just stop, but a bad front end will put you in a ditch somewhere.' (Another way I knew he loved me!) The car had had a new piston ring job and the motor was very stiff. To start, I would jack up one rear wheel, crank until I was exhausted, get the motor started, and let it run with one wheel spinning (up on jack) while I had breakfast. I borrowed a puptent and sleeping bag. Trip took six days. Got new ignition timer at Sparta, Wis. to cure backfiring that scared my Sparta farm family 'host.' Had radiator leaks fixed at Erie, Pa. Brake band on planetary transmission wore out at Albany. Came through Massachusetts on holiday weekend using reverse band to slow car. Made it to Boston. Too expensive to insure and register car in Boston. Left it on M.I.T. campus where, in spring of 1928, it was crashed in M.I.T. auto-polo stunt."

A letter from **George Palo** brings us the sad news that **Victor J. Decorte** died on July 9, 1984 only a few hours after being hospitalized with a heart attack. Vic received both S.B. and S.M. degrees in Course VI, electrical engineering, and followed these with an M.B.A. from Harvard Business School in 1934. During most of his business years Vic was in the petroleum industry, largely on an international basis. Thus he and wife Alice enjoyed a great deal of travel together. Upon retirement in 1966 they went to Rome, Italy to live. Since 1974 they have lived in Florida. Vic was a highly respected classmate and always a loyal supporter of M.I.T. To Alice, on behalf of the class, we extend our heartfelt sympathy.

When you have these notes before you, it will be the beginning of a new year. May we, then, wish you well, good health, and a very good 1985!—**Walter J. Smith**, Secretary, 37 Dix St., Winchester, MA 01890

29

In the October issue of the *Review*, the names of two officers of the class of 1929, who were nominated and reelected, were inadvertently left out. They are **Dexter T. Osgood** of Malverne, N.Y., class agent, and **John J. Wilson** of Marblehead, Mass., estate secretary—my apologies.

Al Moore of Rockville Center, N.Y. writes, "Thanks for the birthday card and the concern you had expressed about my operation. I have recovered from it sufficiently to begin traveling about as much as usual. I was sorry to miss our 55th reunion, but my grandchildren are in the process of graduating from high school and college, and two such cases kept me busy in Michigan during the time I would otherwise have spent on Cape Cod and the M.I.T. campus. My best wishes to all." . . . **Hiram A. Lyke** of Osprey, Fla. and Oconomowoc, Wis. states that he and his wife Jean are in fair health. They still trek back and forth from Florida to Wisconsin with the change of seasons. Their middle son, Ned, graduated with the class of 1954, exactly 25 years later than our class. He sends his greetings to all. . . . **John G. Howell** of Piedmont, Calif. writes: "Still busy with innumerable challenging projects, such as improving the lighting in our local schools and modifying a local hospital's heating system to save energy. Some are for free and some for a fee." John and his wife Katharine have two children and two grandchildren. He lists his hobbies as woodworking, rowing, bicycling, and engineering research.

Frederic Celler of Maitland, Fla. and Paris, France writes, "I had a poor midyear—dislocated my right shoulder, followed by circulatory illness while in Paris which immobilized me for several months. However, I am back to daily swimming and modest golf. Active in international matters in the Orlando area in a modest way. I do not have a computer as yet but do fondle my old

slide rule from time to time." Fred and his wife Margery attended our 45th reunion. His loyalty is divided between his native country France and his adopted country, the U.S.A. For all of his adult life to date, he has been embassador-at-large (in effect, not title), fostering good relations between two traditionally friendly countries. He has been president of the M.I.T. Club of France; director of the American Chamber of Commerce in France (president in 1975-76); commander, European chapter, U.S. Military Order of Foreign Wars (1965-70); and vice-chairman of the American Bicentennial Committee in France. . . . I have a note from **Romeo H. Guest** of West End, N.C.: "I find the Pinehurst area of North Carolina to be a very pleasant place. Many people come here for golf and steeplechase or just plain good living. I traveled so much doing sales work for my industrial construction, so that travel has no appeal to me any more. Thank you for the work you are doing as our class secretary. Best wishes to all." As his hobby he lists "watching the cows come home on my neighbor's farm."

Arthur A. Jones of New Bedford, Mass. writes, "Since my cardiovascular problems of four years ago (three operations), we have curtailed our traveling drastically. However, we do enjoy our home and gardening and occasional visits from friends and relatives." . . . You may have seen on TV about the great fire in Billings, Mont. Our vice-president **L.R. "Bill" Aldrich, Jr.,** reports, "The great fire was about 40 miles from our home. It went through 20 house subdivisions like a blowtorch, and the noise was like a jet taking off. It was like burning up to two-thirds of the area of Rhode Island, which was tough on many people. I haven't talked with **John McCaskey** lately, but he had a graduation conflict which prevented him from attending our recent 55th reunion. As for me, when I learned that **Wally Gale** was not attending, I dropped my plans to attend." . . . **John F. Dreyer** of Cincinnati, Ohio is wondering how an M.I.T.-Harvard joke got all the way to his area: "A student goes to a supermarket on Mass. Ave. between Charles River and Harvard Square and buys some groceries which come to eight items. While going through the express checkout counter marked 'six items or less,' the clerk says, 'Young man, you must be either from M.I.T. and can't read or from Harvard and can't count.' "

In a recent issue of the *Review*, I reported that Hope (Mrs. **George D.) Rogers** of Fairfax, Va., had written. Responding to that, Helen (**Mrs. Perry C.) Maynard,** '24, writes: "Hope is a distant relative of mine. We used to visit each other's home until Rogers moved to the Washington, D.C. area. In the meantime, I had a heart attack and a stroke in 1977, lost my husband, and was unable to write. As a result, I had lost track of her whereabouts until now. It was like a breath of spring to know from your notes that both Hope and her husband George are still alive. Please send her address so I can write to her at once, as I am living presently on 'borrowed time.' " . . . Dr. P. Griffith, daughter of **Frederick Metcalf Thomas** of Old Mystic, Conn., writes that her father passed away on October 26, 1973 of a heart ailment. She says that from 1950 until his death, he wrote books, designed boats, and flew sailplanes.—**Karnig S. Dinjian,** Secretary, P.O. Box 83, Arlington, MA 02174

30 55th Reunion

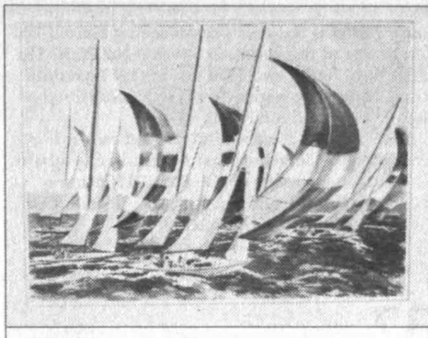
55th Reunion chairman **Joe Harrington** sends a tentative 55th Reunion program. The activities are proposed to begin at the Colonial Hilton in Lynnfield, Mass., on Wednesday, June 5, with a dinner and show of pictures from former reunions. Thursday will be free for daytime sports and sightseeing, followed by dinner at M.I.T. and an evening at the Pops concert. The Friday schedule includes the usual Technology Day events, after which we will return to the hotel for our class dinner, business meeting and speaker. The traditional shore dinner is scheduled for Saturday, June 8. For more information, you can write Joe at 1 Cherry St., Wenham, MA 01984.

Parker Starratt, our class secretary during the years 1935 to 1955, is still living in Hancock, N.H., where his retirement activities include ham radio (K1BUR), church choir, town auditor, and the local historical society. His somewhat off-beat hobby is making simple flutes in different keys from 3/4" white *CPVC* pipe and demonstrating them to various groups. . . . **Morris Shaffer** is still active as coordinator of the Office of Research at the L.S.U. School of Medicine in New Orleans. Last year, he arranged for the creation of a new Sigma Xi Club at the Medical School. The official installation took place in October, 1983; it has now grown to 120 members, and Morris expects it to flourish. He does considerable travelling to attend various meetings; his recent trips have taken him to Montreal for an international congress on sexually transmitted diseases, to San Francisco to squire his wife at a meeting of the American Pediatric Society, and to Toronto as a delegate to the annual international meeting of Sigma Xi. During a trip to New England last spring, he visited **Milton Mezoff,** who is retired but physically and mentally in good shape, and **Saul Sigel**'s widow, who is still practicing pediatrics in New Hampshire. **Les Steffens** reports that he sailed in a Sunfish Regatta in Pearl Harbor in February, 1984, but doesn't say whether he won anything. At the time he wrote, he was about to start a non-musical stage career playing the part of the king in a local Childrens' Theater production of "Sleeping Beauty." . . . **Walter Smith** was founder and president of Process Equipment Co., Inc., a company he established in 1944 as a manufacturer's representative for equipment used in the chemical, petroleum, and power industries. He has retired and is still living in Tulsa. . . . **Hal Spaans** continued to work as an instructor for United Telephone System after retiring from Bell of Pa., but has now "decided to call it quits so we'll have more time to travel and enjoy life." He and Marge live in Wayne, Pa., where he is chairman of the A.A.R.P. travel committee, member of the Town Watch, active in the National Sojourners and Masonic Lodge, and a vegetable gardner. He reports that Edith and **Hank Halberg** stopped to see them on their way from Little Rock to New England to visit friends and relatives. The Halbergs are "very active in the Audubon Society and are considered to be experts, having written articles for both the Arkansas and National publications." About a year ago they took a 3,000-mile trip through Mexico, visiting Mayan ruins and expanding their lifetime list of identified birds.

Last September, Louise and I took a Maupintour trip to central Europe which included a performance of the Passion Play in Oberammergau. While we were en route, I recalled that **Alfredo Gutierez** lived in the area, but I did not have his address with me. Fortunately, our Oberammergau hotel had an area telephone directory in which he was listed, and I was able to reach him by telephone. The result was a delightful evening spent with him and his German wife Anke at a relatively new and impressively large house they have built on a ten-acre plot in the village of Grainau, a suburb of Garmisch. Their younger son, who attends the local "gymnasium," lives at home, and the older son is at the university in Munich. Alfredo's home is in the middle of a popular ski area; he says he does considerable skiing with his sons, which keeps him in good shape physically.—**Gordon K. Lister,** Secretary, 294-B Heritage Village, Southbury, CT 06488

31

This month's news is mostly sad. A letter to the Alumni Association reports, "**Robert J. Fleming,** a retired major general in the U.S. Army Corps of Engineers, died July 14, 1984, at Stanford University Hospital after a brief illness. He was 77. General Fleming graduated from West Point in 1928 and M.I.T. in 1931. He assisted in the construction of Fort Peck Dam in Montana. In 1939 in Hawaii, he was responsible for several construction projects, including the road to the top of Heleakala Crater. As a lieutenant colonel, he became chief of staff, Hawaiian Department Services, in 1942 and deputy chief of staff for the Central Pacific Area also in 1942. He was promoted to full colonel in 1943 and commanding officer of the 1140th Engineer Combat Group in Kentucky. In Europe his group supported the 1st and 9th Armies and was in charge of the occupation of the Rhineland province and the Ruhr Valley in Germany. After World War II, he had assignments with the Corps of Engineers in Europe. He was promoted to brigadier general in 1955 while serving in the New England Division. In 1957, he returned to Europe as commanding general, Theater Army Support Command, in France. He was promoted to major general in 1961 while serving as division engineer in Dallas, Texas. In 1962, President Kennedy appointed him governor of the Canal Zone and president of the Panama Canal Co. Among the many honors he received were the Distinguished Service Medal, the Legion of Merit, the Bronze Star, and an Army Commendation Medal. France made him an Officer of the Legion of Honor and awarded him the Croix de Guerre; pre-communist Czechoslovakia made him Commander, Order of the White Lion and gave him the Czech War Cross; the Soviet Union inducted him into the Order of the Fatherland during World War II; and Panama inducted him into the Order of Fasco Nunez de Balboa. He was a member of the Engineering Honor Society of Phi Kappa Phi, West Point Chapter."



The late architect artist J. Gordon Carr, '29, traveled extensively and painted people, boats, and the sea. His family dedicated this watercolor of sailboats and spinnakers to the Second Congregational Church of Greenwich, Conn.

We also regretfully report the death of **Harold M. Wilson** on August 19, 1984, after an illness. He was senior vice-president of Gen-Rad, where he worked for 28 years, retiring in 1971. According to a newspaper clipping, Harold began his career as a design engineer at Spencer Thermostat. In 1942 he was a project engineer at Research Construction Co., and joined General Radio Co. (now Gen-Rad) in 1945. He served on the Bolton Board of Selectmen, as well as the Bolton Advisory Board, Finance Committee, and Conservation Commission. He was a registered professional engineer, a senior member of the Institute of Electrical and Electronics Engineers, and a member of the American Society of Mechanical Engineers. **Claude Machen,** our treasurer and vice-president, writes, "Another sad one for me. Harold ('Ike' to me) was my close friend since I arrived in Belmont, Mass., in 1924, fresh from my way out in the backwoods of Virginia. I was best man at his wedding in 1930—and about two years after Clare died (around 1936), I was best man

again when he married Dorothy. I'll miss him."
Larry Barnard writes, "I recall seeing Harold Wilson at one of our reunions—was it the 25th? He must have had a good life out in that beautiful town in the 'apple-growing belt.' Understood at that time he had a farm."

Sorry to have to report all the sad news. It is a duty of Class Secretary that I don't like.—**Edwin S. Worden**, Secretary, P.O. Box 1241, Mount Dora, FL; **John Swanton**, Assistant Secretary, 27 George St., Newton, MA 02158; **Ben W. Steverman**, Assistant Secretary, 2 Pawtucket Rd., Plymouth, MA 02360

32

A class secretary's delight was the letter I recently received from Rebecca and **Arthur Marshall**. They are busily engaged in many varied activities. He writes, "I attended the Olympics in Los Angeles. It was a super great experience. Two of our grandchildren—one in Marlboro, Mass. and the other in Claremont, N.H.—were married during the summer. Rebecca and I anticipate the possibility of being great-grandparents within the next couple of years. How about that? On July 26, 1984, I conducted the Springfield Symphony Orchestra at an outdoor concert at Stanley park in Wesfield, Mass. They tell me that about 5,000 people attended.

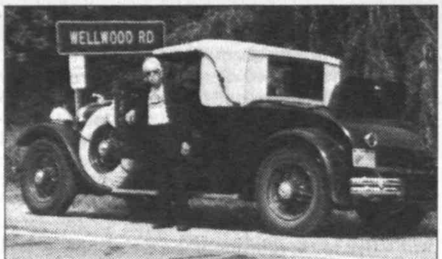
"Rebecca and I will be on a trip to Israel between October 15 and November 5, 1984. This will be my 31st visit to Israel. We were first in Palestine in 1933 when I took my band aboard the *Vulcania* on a cruise around the Mediterranean. On September 20, I attended a reunion of my Newton High School Class of 1928. Midge and **Bill Pearce** and Polly and **Ed McLaughlin**—also Newton Class of 1928—were there." Art would like to see a mini reunion and would be glad to help plan one.

I also received a welcome card by Savina and **Manny St. Denis** postmarked Budapest. They are on a leisurely four-month romp through Europe (Italy, Greece, Turkey, Yugoslavia, Austria, and Hungary). Manny, when you return to Honolulu, you should share with your classmates (by letter) some of your experiences and observations on this unusual jaunt. I recall conversations I had with you at our 50th reunion. Because of your involvement in defense projects, I asked you which country, Russia or America, was the stronger in nuclear power. You thought for all practical purposes they were equal. I felt there would be no nuclear security until there was one world authority with complete nuclear control. You said President Eisenhower had suggested this. We agreed the world would not think of such a plan until one or two cities were destroyed by terrorist nuclear attacks.

Twenty-five years ago the U.S. put on an exhibition in Moscow of prefabricated homes. **Albert Dietz** and several other members of the M.I.T. staff were deeply involved in the last-minute engineering design of some 90 glass fiber-reinforced plastic "parasols" 24 feet tall and 16 feet across for three special pavilions. The ideas were so new that we wind-tested them with the slip-streams of a couple of bombers. Eisenhower intervened with the plastics industry to finance them. He went over to see that they were erected properly. It was quite an undertaking. In July, a 25th anniversary party was held at the Smithsonian. Nixon showed up and it was featured on National public television. Ruth and Al enjoyed the party.—**Melvin Castleman,** Secretary, 163 Beach Bluff Ave., Swampscott, MA 01907

33

Don't these class of 1933 men get around! **Dayton Clewell** writes that by the time this sees print he will have been to China for three weeks as part of the People to People Citizens Ambassador Program. A group of 20, having managed large engineering projects, were asked to share experiences with engineering groups in China. It will be interesting to hear his report. Dayt says that he goes to Florida every other month and will stop by to see the Whittons someday. All of you are welcome. With our present living arrangements, you will be no trouble, so come on by.



"There are no ditto marks in my diary," says Robert C. Wellwood, '33. Last summer he drove over 3,000 miles in his '29 Lincoln.

Bob Dillon postcards from Japan that the south island is warm in the summer and perfectly beautiful and the people most pleasant. Their cruise had a small crowd and so was more enjoyable than some trips. Bob and Alice live in La Marque, Tex., where he worked with Carbide until retirement. . . . **Warren Henderson** spent so many years reading classmates' almost illegible letters that he now prints his holographs . . . write me anyway. We'll give your letters the best interpretation possible.

Word has come this month of the death of **Paul W. Lefevre** last summer in Brattleboro, Vt. Paul was a design engineer for the Baden Corp. when he retired. . . . With the new alumni directory, we will be able to count the names and see how many classmates are left of the more than 600 who graduated that June morning so long ago.—**Beaumert Whitton**, Secretary, 5150 Sharon Rd., Cottage 112, Charlotte, NC 28210

35 50th Reunion

In case some of you could not put names to all the '35er faces in the top photo on page A9 of the October *Review*, they are (left to right) **Ned Collins**, **Bernie Nelson**, **John Taplin**, **Arthur Cohen**, **Allan Mowatt**, **Nix Dangel**, **Leo Beckwith**, **Warren Seamans** (our new honorary member) and **Pete Grant**. . . . It was good to receive a newsy letter from **Walter "Stockey" Stockmayer**, our resident diplomat at Dartmouth College. He writes, "Sure, I'll come down on Thursday to row (at our 50th). But I also want to leave you an out—if enough old *real* M.I.T. oarsmen like **Barney Freiberg** want to go out, you can dump me. I would be disappointed, of course, but I sure would understand. You recall I did essentially no rowing at M.I.T., taking it up seriously only in 1935-37 at Oxford. Well, I wonder what the chances are. At our 40th we had to co-opt **Jake Leeder**, who had never sat in a shell before and who covered himself with glory by not catching a crab!"

"Sylvia and I had a seven-week trip to Europe in March and April. We drove across southern France, starting in Bordeaux and skirting the Pyrenees, finally ending in Antibes (near Cannes) for a meeting. Then a month in England, mainly in Oxford, followed by short stops in Denmark and Holland (for science, mainly) before getting home and planting a late garden, which however has yielded quite a few veggies at that. Then in August I went back to Europe alone, for a meeting in Prague and two full weeks in the Alps. I didn't get any higher than about 3,600 meters, and was on a rope only twice, but daily average for mileage and vertical ascent wasn't too awful. I lost eight pounds around the rubber tire, but of course it's almost all back now, alas."

"Like many of us, I passed my 70th birthday in April. In July about 50 of my former students and scientific co-workers gathered here at Dartmouth for a short symposium. This included both M.I.T. and Dartmouth types, and of course was both gratifying and embarrassing. Now we are looking forward to next June."

Can you guess which college football team is leading the New England Club Football Conference of eight teams at the end of the first month of play? M.I.T.—undefeated in its first three games!! . . . **Sam Brown** writes of his and Natalie's summer activities: "Our trip in Europe this summer was just great. We flew to Amsterdam from New York and were joined by the 30-odd others from our church in Florida, including the pastor and his wife. The day after they arrived we all were bussed to Nijmegen for evening boarding of the *M.S. Austria*, one of the Koln-Dusseldorf line's new boats, for a four-and-one-half-day upriver Rhine cruise. Upstream of Strasburg the boats travel the Rhine Canal rather than the river, and there are nine large locks. Land side trips were taken at Cologne, Heidelberg, and Strasburg. Debarking at Basel, we went by bus to Hergiswil, a village on Lake Lucerne about seven miles south of the city. Then on to St. Moritz, via Lichtenstein, and to Oberammergau for the Passion play, staying two nights in a German family guest house. From there we had two long bus rides, first to Baden-Baden, and then on (via Luxembourg) to Bruges, Belgium. After two days the rest of the people flew home, but we went by train to Paris. Despite one rainy day, we thoroughly enjoyed our fourth visit to Paris; to us it is a city that we know well and rate most highly. We'll see you at the reunion in June." Many thanks to Stocky and to Sam for their letters; it's always good to hear from them.

Your reunion committee met at M.I.T. on September 6 and took a big step in finalizing our plans. Those attending included: **Chet Bond**, **Al Johnson**, **Leo Dee**, **John Taplin**, **Bob Lindenmeyr**, **Leo Beckwith**, **Nix Dangel**, **Prescott Smith**, **Bernie Nelson**, **Ned Collins**, and your secretary. Kay Henry represented the Alumni Office. The big weekend begins on Wednesday, June 5, where you will check in at McCormick Hall and be assigned rooms and parking. If you arrive from 2 p.m. on, you will be met by one or more of the following greeters: **Leo Beckwith**, **Pete Grant**, **Bob Forster**, **Ned Collins**, **Allan Mowatt**. The crew will row at 10 a.m. on Thursday. The rest of the program will reach you soon by a letter being sent out by the Committee Chairmen **Goffe Benson** at M.I.T., **Prescott Smith** at Wianno, **Bob Lindenmeyr**, Registration and Class President **Bernie Nelson**. Mark up your calendars for June 5-9, 1985.

I am sorry to report the death of **David D. Terwilliger** on August 27, 1984 in Walpole, Mass. He was very active in M.I.T. alumni activities, and we used to see each other regularly at the telethons. He was also a member of the 50th reunion committee. I am sending a message of sympathy to his widow on behalf of his classmates.

Will all former oarsmen interested in rowing about one-half mile each way on June 5, who have not already signified their interest, drop me a note confirming their date with destiny?—**Allan Q. Mowatt**, Secretary, 39 Congress St., Apt. 5, Nashua, NH 03062

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A recent note from **Pete Weinert** will bring us all up to date on doings in the Weinert family. He writes that upon retiring, "after 44 years of enjoyable and challenging work with Universal Oil Products, Inc.," he started Petropete Corp. to provide services in petroleum engineering and training. Subsequently he organized and supervised training courses for Indonesian engineers in Jakarta, French and other engineers in Paris, and

The 1984 Bronze Beaver to Alice H. Kimball, '36, for "the depth of her commitment to the Class of 1936 [as its secretary], and the breadth of leadership she has contributed to local and national alumni activities."

last year for Nigerian engineers in Warri, Nigeria. He enclosed a fascinating account of their experiences in Nigeria put together by Jean Weinert. I found it very interesting reading and will try to share it with as many of you as possible. Pete is looking forward to our 50th. . . . **Tony Hittl** reported on a west coast mini-reunion arranged by him and **Laddie Reday**. More on that later. This morning in the mail was a postcard from Laddie from Sofia, Bulgaria, telling of mountain climbs in Greece (Mt. Olympus), Jugoslavia, and Romania.

Your secretary was nearly overwhelmed to learn in July that she was to receive a Bronze Beaver in recognition of my "years of service to the class." I doubt if it is deserved, but I went to Toronto to pick it up in person and am very proud to have it.! . . . A note from **Frank Phillips** said that he and Phoebe were readying their Vermont home to rent and were going to look at the southwest as a possible place to move—away from the rigors of New England winters. It will be interesting to learn of their final decisions. . . . By the time you read this, plans for the 50th reunion will be in the works. I will welcome your suggestions and comments right now! Eighteen months is not a overlong lead time.—**Alice H. Kimball,** Secretary, P.O. Box 31, West Hartland, CT 06091

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Virginius N. Vaughan, Jr. of Chatham, N.J. has made 75 to 100 trips, mostly to various parts of Europe but including Hawaii, the South sea islands, Australia, Japan and Africa. Most trips were for business but included vacation trips with his wife Sally. Sally is interested in art—painting (oil and water color) and sculpture. Virginius is an IEEE fellow and retired in 1980 from AT&T company headquarters staff as director of data communications. He is now working as a consultant—computer communications—with several clients in Washington, D.C. and New York City (principally the Department of State). He received an honorary degree as doctor of science from Randolph-Macon College in Ashland, Va. Virginius writes, "The variety in life is wonderful! It's true I have had only one wife, but she has provided plenty of variety in that department." For hobbies he has Boy Scouts, teaching, sailboat racing, and house and garden work.

Albert H. Shulman is still living in Hartford, Conn. and makes frequent trips to his farm in Bennington, Vt. In October 1984, Albert's four children (Marc, Tina, Amy, and Sally) plus spouses and eight grandchildren surprised Albert with a party for his 70th birthday. Al and Rachel, expecting a small family party, returned from Vermont to find 75 people and a band. The class of '37 was represented by Genevieve and **Len Seder**, Dorothy and **George Rosen**, Pearl and **Lester Klashman**. A delightful skit was put on by Albert's children, their spouses, and grandchildren, humorously showing their love and respect.—**Lester M. Klashman**, Assistant Secretary, 289 Elm St., Medford, MA 02155; **Robert H. Thorson**, Secretary, 506 Riverside Ave., Medford, MA 02155

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Thanks to those of you who sent us Christmas cards. And to those of you who didn't, your secretary would appreciate any sort of a communication which would serve to keep us all posted on the comings and goings of 1938. Many of you have seen the inscription on the clock tower in San Francisco's Chinatown: "The time is later than you think."

Don Severance had lunch in Houston with **Bob Park,** who just retired from Texaco. Bob now has more time to devote to his two main hobbies: bridge (at which he's a life master), and a 22-piece jazz band (which plays as a non-profit group at charitable and civic affairs). They have raised over one and one-half million dollars for charity. Perhaps, if we can't get them all to come to our 50th reunion, Bob will at least bring some tapes for us. . . . **Connie Roosevelt** is in France ballooning with **Pete De Florez.** Muriel and **Norm Leventhal** have just returned from China. . . . Jean and I married off a son in Norway and then spent five weeks coming back through Norway and Britain. . . . Since I can't reach our distinguished class secretary, I assume that he and Sandy are away again.

Paul Black, reports the demise of **Ross Cooper** late in August. We last saw Ross and Janet at the mini-reunion in June. . . . Another death, also in August: **David Sargent**. Dave had retired as a special sales engineer with Westinghouse, where he had worked for 40 years. He was a resident of Wellesley.—**Armand L. Bruneau, Jr.,** Secretary, 663 Riverview Dr., Chatham, MA 02633; **G. Edwin Hadley,** Assistant Secretary, 50 Spofford Rd., Boxford, MA 01921

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Wood Thomas writes: "I never thought I would miss my 45th reunion, but I did, and without forethought. Over Memorial Day Dot and I were visiting some friends in northern Lake Huron. Their pilot and I went island hopping in their helicopter, and on a takeoff a wave tripped us and we crashed and sank. The cabin filled with water immediately. Neither of us could open the doors. There was not enough time and I lost consciousness. Finally Dick got out and up, and finding I had not come up, he went back down and pulled me out. Later our friends rescued us. I was flown to Detroit's Ford Hospital where I knew little for two weeks. I've been home since the first of July, and with Dot's help, I have picked up energy and some of the 35 pounds that I lost. I am back to work again, part time, but it's good to be alive.

"There are so many loving, caring, and thoughtful people who did everything possible to keep me alive, and all their "good wishes" helped pull me through bad times. The greeting card I got from old friends and thoughtful classmates at the reunion made me misty-eyed. I appreciated that so much. Thank them for me in the *Review*. An experience like that provided me with a new insight on life, but I'm not recommending my method. Best regards to you and the '39ers."

Leo Weiss (at Washington-Baltimore) and **Jim Barton** (at Seattle) are active in M.I.T.'s Enterprise Forums. These forums are held bi-monthly and nationwide. They provide ways for smaller companies to explain their business plans, including detailing their frustrating and unsolved problems, to a panel and an audience of experienced businessmen, who then may choose to volunteer suggestions and advice.

Hilda and I announce our migration to the Pacific Northwest.—**Hal Seykota**, Secretary, 1415 Seacliff Dr., N.W., Gig Harbor, WA 98335

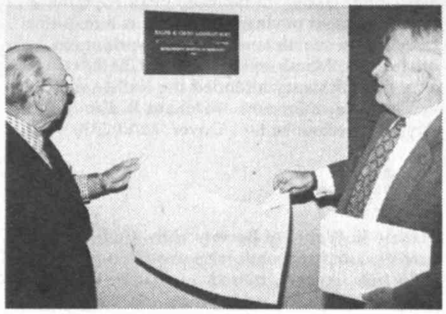
40 — 45th Reunion

Ed Bernard, our class treasurer, is attempting to locate class member's widows, who are interested in class activities, such as the upcoming 45th reunion. Only a few are listed with addresses in our records. If anyone has any addresses for the following, please send to Ed at 57 Winn St., Belmont, MA 02178 (or to me): Mrs. **Harry R. Buch,** Mrs. **James H. Campbell,** Mrs. **Richard M. Crossan,** Mrs. **Frank G. Denison,** Mrs. **Andre F. Lernan,** Mrs. **John J. Piotti,** Mrs. **James F. Sheehan,** Mrs. **James W. Watkins,** Mrs. **Russel E. Winslow.**

Ed also indicated this past September that he was planning to mail invoices for 1984-85 class dues, plus first announcements on the 45th reunion. I assume you have received this material.

A clipping from *Engineering Societies of New England* announced that **Lewis R. Aronin** had been elected to the executive board of this publication for 1984. Lewis is a materiels engineer with the Ballistic Missile Defense Materiels Program at the Army Materiel and Mechanics Research Center in Watertown, Mass.

I received a very interesting, informative letter from **Bill Kather,** who is now "mostly retired." Bill moved from Chicago, Ill. to: 2389-3A Mariposa, West Laguna Hills, CA 92653, and wants to hear from classmates in the Los Angeles area. This past April, Bill married a lovely lady, Betty, who had also lost her mate. In rapid succession they each sold their condos, purchased a new one and moved to Laguna Hills. In an investment discussion group he renewed his friendship with **Jack Schuam,** whom he hadn't seen since graduation—bringing M.I.T. expertise to investing "in puts and calls." He also successfully merged his 16-year-old business with another group of chemical consultants to form Young and Kather Associates, Inc. While still in Chicago, he had a small



President Paul E. Gray, '54, unveils a plaque designating the first floor of the Laboratory for Manufacturing and Productivity the Ralph E. Cross Sr. ('33) Laboratories for Manufacturing and Automation. Mr. Cross is retired chairman of Cross and Trecker Corp.

The 1984 Bronze Beaver to Thomas F. Creamer, '40, for his long record of service to M.I.T. as "an officer, director, and chairman of the M.I.T. Alumni Center of New York, vice-president of the Alumni Association, member of the M.I.T. Corporation, and several Corporation Visiting Committees."

reunion with **Arnie Wight, Hal Davis,** and **Marsh Bearce**. Arnie, a member of the New Hampshire legislature, is busy in his new area of specialization—toxic and nuclear waste. Hal is a manufacturer's representative and is also working on other deals. Marsh retired to Port Charlotte, Fla. after he and Nancy attended the Kather wedding.

All the news for now.—**Donald R. Erb,** Secretary, 10 Sherbrooke Dr., Dover, MA 02030

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Stanely E. Weber of Beverly Hills, Calif., group executive and corporate vice-president of Litton Industries, recently retired. . . . **James F. Healy** of St. Petersburg, Fla. is chairman and chief executive officer of Milton Roy Co. (Come on you two, we need to know a little bit more about your life.)

We received a news release from the Scripps Institute of Oceanography: **Jerome Namias** received an honorary doctorate from Clark University, Worcester, Mass. His research interests pertain to short-term climatic variations and long-term weather predictions. Jerry was born in Bridgeport, Conn. and won a citation during the war for his weather forecasts for the North African invasion. He presently lives in La Jolla, Calif., conducting research at Scripps. In 1972, he received an honorary doctorate from the University of Rhode Island, and in 1981, the Sverdrup Gold Medal of the American Meteorological Society. Congratulations!

J. Lester Klein writes that he retired in July from Bird-Johnson, where he served as vice-president of engineering and development. He will continue with consulting, but will concentrate on tennis, skiing, and playing with his grandchildren. . . . **Martin L. Ernst,** vice-president of Advanced Information Technology, Arthur D. Little, Inc., talked about artificial intelligence at a forum in June. He predicts that non-Von Neumann computer architecture will greatly enhance AI's future applications and make very advanced robots possible.

Harold E. Dato of Wauconda, Ill. died on April 26, 1984. Those of us that lived in the "dorms" remember Harold as a cheerful and studious student, very active in student affairs. "Did Harold write for the *Tech*?" Please write your secretary, share your memories of Harold Dato with all of us.—**Joseph E. Dietzgen,** Secretary, Box 790, Cotuit, MA 02635

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Another month and another empty envelope from the *Review*, i.e., no news. Fortunately, there is always **Jim Hoey,** and a quick call to him produced enough information for some class notes.

Jean Hartshorne has returned to the Boston area after a month in Kenya. Jean recently retired from the family insurance business, Charles F. Hartshorne and Son. We hope someone trustworthy is watching the store. . . . An autumn visitor to Yarmouth was the sage of Palm Springs, **Dick Feingold**. Dick and Jim Hoey took a ride with **Gene Eisenberg** aboard the Eisenberg sloop, *Limbo*, departing Woods Hole for a cruise of the Vineyard Sound. Dick is reported to be contemplating a retirement move—from the sands of the desert—to the sands of Cape Cod. In shoes and spinach it's all the same.

J.H. and I would certainly welcome additional news sources.—**Bob Rorschach,** Secretary, 2544 S. Norfolk, Tulsa, OK 74114

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We always appreciate the start of a new year: the calendar year this time. Once again we have the opportunity to take stock of our lives and make attempts to alter them in some small way. Whether or not we are successful becomes a moot question.

Pierre H. Boucheron writes that he and his wife Charlotte live near Charlottesville (Va.) in a house designed by their son Robert. (Daughter Charlotte has two liberal arts degrees and is a docent at Winterthur; son Pete III is a senior tool and diemaker with GE; and son Edward is working on his Ph.D. at RPI.) Pierre says that wood stoves heat 95 percent of their home. Their three cords of wood, collected from their land, weigh 12 tons (wet) and must be handled six times from stump to stove.

Melissa Teixeira reports that she received a 1944 Technology Day mug, along with the sheet music for "Sons of M.I.T." (March version). This was first presented and sung at the Alumni Dinner in February 1944. . . . **Jacquelyn M. Findlay** was a member of the 1983-1984 Alumni Fund board and joins your secretaries in thanking you for your generous contributions to the Alumni Fund and the Class of 1944 Scholarship Fund.—**Melissa Teixeira,** Secretary, 92 Webster Park, West Newton, MA 02165; **Louis Demarkles,** Assistant Secretary, 53 Maugus Hill Rd., Wellesley, MA 02181; and **Andrew Corry,** Assistant Secretary, Box 310, West Hyannisport, MA 02672

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Sorry for spacing out the holiday issue, but there weren't any inputs, and besides I was off building trails in the Collegiate Range when deadline time arrived. Shortly thereafter (October 15, 1984) we commenced our long-planned California odyssey, supply-shipping son Chris' bizarre sound machines to Los Angeles in the pickup and proceeding on to dozens of old-time friends along the coast from San Clemente to Mendocino and points east. Stayed one night with old roomy **Mario Vinci** in his cliffside aerie overlooking Laguna Beach, where we dined on pasta and calamari and other goodies. After numerous adventures we passed through Incline Village, Nev., to see if **Bill Cahill** was alive and well, but found him off on a trip. Then on to our final stop with **Pauline Glazier Teague** in Fallon, Nev., in their "little house on the frontier." It was a warm and wonderful experience. Wish we could all meet there for a reunion. Pauline is alive and exceedingly well.

Remarkable notice from our Department of Ocean Engineering about **Marshall Tulin,** one of our Course XVI expatriates, now Presidential Professor of Ocean Engineering at University of California, Santa Barbara! Internationally acclaimed for his work in super-cavitation, he delivered the prestigious Georg Weinblum Lecture on "Surface Waves from the Ray Point of View" in Hamburg, Germany on September 3, 1984. Marshall, a Hartford, Conn. native, went from M.I.T. to Langley Field to David Taylor Model Basin to Office of Naval Research, and so on, to Santa Barbara. Quite an achievement, Marshall! See you at the 40th? Maybe you and **Beverley Beane Graham** ought to come and compare notes.

Speaking of the 40th—reunion, that is. . . . Isn't that what's on everyone's mind? Did you get **John Gunnarson**'s questionnaire on where we want to reune and what to give for our class gift? Of course not, unless you're on the reunion committee. Anyhow, I feel my job is to drum up interest for "the whole shoot and kaboodle," so I'm asking all of you critters out there in the "terrashphere" what would entice you to come and contribute to our reely-big-show (time, place, program, gift, etc.). Drop me or John a card *but soon*! John's address is: 32 Farmer's Cliff Rd., Concord, MA 01742.

Our memorial note, in case you haven't been told, is about Dr. **Jim Moore,** born in Dublin Ireland, but brought up on Long Island, who went through V-12 in Course II. Jim went on for his Ph.D. at Columbia (1957) and became professor of physics at Hofstra University, where he was given the Distinguished Service Award for Natural Sciences as "a person who, for students and colleagues alike, stands as a model for the joy of science. His appreciation of the beauty of scientific discovery and insight has been at the heart of his many and varied contributions to learning at Hofstra." Jim died August 7, just before his 59th birthday. If you knew Jim or care, you may call his wife Sophie for details: (516) 473-1569. Keep the faith.—**Jim Ray,** 2520 S. Ivanhoe Pl., Denver, CO 80222

The 1984 Bronze Beaver to Peter M. Saint Germain, '48, for his "extensive involvement with and loyal commitment to M.I.T." As general chairman of the Alumni Center of New York, he is actively building a strong, viable M.I.T. presence in the city.

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Stan Abkowitz, president of Dynamet Technology of Burlington, Mass., was elected chairman of the Boston chapter of the American Society for Metals (ASM) for 1984-85. ASM is an international professional society of materials scientists and engineers with 53,000 members, including 1,000 members in the Boston chapter. Dinner meetings are held monthly at the M.I.T. Faculty Club. At this year's ASM meeting Professor Nicholas Grant of M.I.T. will tell how the technical and scientific community is beginning to understand how rapid solidification processing can produce alloys that meet exacting demands.

Judith Turner writes that her firm has been servicing American multinational companies in Stockholm. Her architectural practice, 2 Arkitekter AB, located on the island of Lidingö (part of the beautiful Stockholm archipelago), has won first place in two architectural competitions recently. She has just returned from a nationwide U.S. survey of the department store planning for a Swedish store chain. Judith's address is Tjädervägen 21, 18140 Lidingö, Stockholm, Sweden.

Harrison Rowe has retired from Bell Laboratories after almost 32 years in the radio research lab and has been appointed to the newly endowed Anson Wood Burchard Chair of Electrical Engineering at Stevens Institute of Technology. Harrison's major contributions to a wide range of subjects in communications are in the areas of behavior of nonlinear elements, electromagnetic theory, and noise and modulation theory. A fellow of IEEE, he was awarded two major prizes for his research. He is the author of 40 publications and holds five patents.

George Fountas continues using the chemistry he learned at M.I.T. He has been formulating specialty chemicals for over 25 years. Currently he is with George Mann Co. in Providence, R.I. He has started a new division for them and built another success from scratch. George and his wife Agnes live in nearby Attleboro. Agnes has increased her real estate brokerage into a successful business. George has a real estate license, and has made his shares of sales. George and Agnes flew to Greece in the spring and chartered a sailboat. They cruised in the Greek islands for two weeks. They also own a sailboat and regularly race and cruise in Narragansett Bay. George has soloed in a single engine plane. A few more lessons and he will be taking Agnes along for trips around New England. Their daugther is a physician.—**Marty Billet,** Secretary, 16 Greenwood Ave., Barrington, RI 02806

The 1984 Bronze Beaver to E. Milton Bevington, '49, for service to his class, the M.I.T. Alumni Fund, and the Alumni Association in a wide spectrum of tasks and positions. His advice, counsel, and leadership have been continuously sought, and each request has been met with cordiality, enthusiasm, and commitment. He represents the core leadership of alumni in the Atlanta area.

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Having been warmly welcomed to the *Review* by Sandra Knight, alumni news editor, and having had **Paul Weaver** write the first two sets of class notes within my term of office, I know I have been fortunate. However, I look forward to 48 more sets of class notes taking us into 1989 and *know* I'll need your help to obtain information about classmates. Please keep those cards and letters coming!

Congratulations to **Richard D. Morel** on being elected chairman of the board of Algonquin Gas Transmission Co. He has been the president and chief executive officer of Algonquin since 1979. . . . **Eric Howlett** has developed and patented a 3-D camera and a viewer to see the pictures. Holett's company, Pop Optics Lab, is currently distributing the system to stereo buffs and is aiming for a general market. See you in 3-D! . . . Reverend **Lloyd Jonas**, counseling pastor of the Forestdale Baptist Church in Sandwich, Mass., spent six weeks in Great Britain as guest of the British Association of Biblical Counselors. Reverend Jonas is the New England director of the National Association of Nouthetic Counselors.

Ernest Barriere retired from General Electric last spring. He plans to winter in Florida and spend summers on Pontoosuc Lake in Pittsfield, Mass. Enjoy it! . . . As many of us approach retirement age, we also have more frequent losses of classmates. We regret the death of **Richard Sunback** of Meadville, Pa.—**Barbara F. Powers**, Secretary, 39 Mount Vernon St., West Roxbury, MA 02132, (617) 323-1539

50 35th Reunion

Albert Rand is presently senior vice-president and director at Dynamics Research Corp. in Wilmington, Mass. . . . **Bruce L. Shakeley** has retired and is now consulting on metals processing. . . . **Enders A. Robinson** is the recipient of the 1984 Donald G. Fink Award for his paper, "A Historical Perspective of Spectrum Estimation." The award, which was established in 1979, is given for the outstanding survey, review, or tutorial paper in the transactions, journals, and magazines of the IEEE societies or in the proceedings issued between January 1 and December 1 of the preceding year. The award, which is supported by the IEEE Life Member Fund, consists of a certificate and $1,000.

Charles "Fitz" Grice, president of Grice Ocean Engineering, Inc., along with Moacir Fortes, a renowned tour guide with 20 years experience, from Manaus, Brazil, have started a venture called Amazonia Expeditions. A 62-foot boat, the *Laura*, with cabin space for 14 people, is currently under construction in Novo Airao, Brazil, with an estimated completion date of March 1, 1985. Some of the equipment on board will include a recording depth sounder, a Celestron C5 telescope for astronomy and photography use, and directional microphone recording equipment for bird and animal sounds. In addition, the *Laura* will have two outboard-powered canoes for side excursions. The *Laura* will be available for charter at an initial rate of $1,400 per day, including food, fuel, and crew to organizations desiring to plan their own itinerary. If you are interested, get in touch with "Fitz," Box 556, Manvel, TX 77578.

William H. Enders, vice-president, Business Terminal Products, of GTE's Telephone Operations Group, has been recently transferred to Connecticut. He and his wife, Jean, are delighted to be situated in New England again. . . . We regret to announce the deaths of **Michael Dubitzky** and **Sylvia R. Pollis.—John T. McKenna, Jr.**, Secretary, 9 Hawthorne Pl., 10-H, Boston, MA 02114

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A recent letter from **Fred Brecker** tells us that he and Sandi brought their oldest, Deanne, to Providence to start her freshman year at Johnson and Wales College. They now have two boys at home, ages 15 and 11, and are concerned about the "empty nest" fast approaching. (Don't worry; as many of us can attest, our children keep coming home to live for many reasons—even after they graduate.) Fred tells us he's in contact with one of our classmates, **Frank Hartzell**, who lives in Wynnewood, Pa., near Philadelphia and is vice-president of Site Engineers, Inc., a soil and foundation consulting firm in Cherry Hill, N.J.

We just received notification that **William Blackwell**, senior architect with Bechtel Civil and Minerals, Inc., working on both domestic and international projects, has had a book published—*Geometry in Architecture*. The book offers a basic review of the relationships that exist in linear design and provides a foundation for creating structures with symmetry, harmony, and order that meet the needs of modern society. A past director of the San Francisco chapter of the American Institute of Architects, he is currently a member of the San Francisco Planning and Urban Research Association.

From a Texas A&M news release, we learn that **Herbert H. Richardson** was appointed dean and vice-chancellor for engineering at that university, effective October 1, 1984. He will have responsibility for the 11,600 students in the college of engineering and for three of Texas' engineering related research and public service agencies. Following service in the U.S. Army Ordnance Corps., designing nuclear blast instrumentation, Herb returned to M.I.T. and rose through the academic ranks to professor of mechanical engineering. He served as first chief scientist of the U.S. Department of Transportation from 1970-72, and was appointed head of mechanical engineering after returning to M.I.T. in 1973, where he formed the Laboratory for Manufacturing and Productivity, among his many activities. He was appointed associate dean of engineering at M.I.T. in 1982.

Another of our classmates in the academic world, Professor **Allan S. Hoffman** of the Center for Bioengineering and Department of Chemical Engineering, University of Washington in Seattle, was awarded the 1984 Clemson Award for outstanding contributions to the scientific literature of biomaterials at the 2nd world congress on biomaterials in Washington, D.C. As we mentioned in our January 1984 class notes, he has also been president of the Society for Biomaterials this past year.

Verrill M. Norwood was appointed vice-president of environmental affairs for the chemicals operations of Olin Corp. at the corporate headquarters in Stamford, Conn. Verrill joined Olin in 1973 and has held various management positions there in the process engineering field, where he has obviously made good use of his S.B. in chemical engineering from M.I.T. and an M.S. in chemistry and metallurgical engineering from the University of Michigan. . . . We are saddened to hear of the passing of Professor **Hugh Muir** in Castle Cove, Australia on June 26, 1984, and we offer our sincerest condolences to his wife, Valerie.—**Wolf Haberman**, Secretary, 41 Crestwood Dr., Framingham, MA 01701; **Joseph M. Cahn**, Assistant Secretary, 289 Bronwood Ave., Los Angeles, CA 90049

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Members of the Class of 1956 should look forward to attending the 30th Reunion in June, 1986, at the Sheraton Islander on Goat Island, Newport, R.I. **Ron Massa**, chairman of the 30th Reunion Committee, is making suitable arrangements at one of New England's finest resort hotels. Further details will be announced as they become available.

Andrew J. Viterbi was awarded the 1984 Alexander Graham Bell Medal of the Institute of Electrical and Electronic Engineers in recognition of his "fundamental contributions to telecommunication theory and practice and for leadership in teaching." In addition to his responsibilities as president of *M/A-Com Linkabit*, a company he founded in 1968 with Irwin M. Jacobs, Andrew is also adjunct professor of engineering and applied science at the University of California, San Diego. He has been a member of the National Academy of Engineering since 1978, fellow of the IEEE since 1973, and has served on the Visiting Committee for Electrical Engineering Departments of M.I.T. and the Technion, Israel Institute of Technology. In addition to his S.B. and S.M. degrees in course VIA, he received a Ph.D. in electrical engineering from U.S.C. in 1962.

Irwin Dorros writes to describe some of his recent experiences as an A.T. and T. executive, which he describes as frustrating, challenging, and the most exciting years since he left M.I.T. He joined Bell Labs upon graduating from M.I.T. in 1956. While there, he was also awarded an Eng.Sc.D. in electrical engineering from Columbia University. In 1978, he was transferred from Bell Labs to the parent A.T. and T. as an assistant vice-president in charge of network planning. Because of events beyond his control—that is, the government's antitrust suit against A.T. and T.—he did little technical planning, but spent most of his time in Washington, appearing before the courts, Congress, and the F.C.C. He became so involved in the litigation that he was awarded a mock honorary law degree from the many lawyers he worked with. As a climax of that activity, he was part of a small group of Bell executives that negotiated the settlement of the antitrust suit with the Department of Justice. His next assignment was to assist in the planning and execution of the dismantling of the Bell System. In November, 1982, he accepted his current position as executive vice-president, technical services, of Bell Communication Research (Bellcore). Bellcore is a new company, born out of the divestiture of the Bell Operating Companies and owned by the seven new regional companies, which will assure these companies the availability and application of new technology, and presumably provide many of the services formerly provided by Bell Labs.

Warren Briggs wrote last May to express his and Renata's regrets at not being able to attend the May 15 dinner-reunion because of prior travel commitments. Because of future availability of fewer students, Warren is now doing "marketing" and "competitive strategy" as well as teaching it at Suffolk University's School of Management. Warren and his colleagues thus have become involved in a series of conferences on computer software, which, by the time this article appears in print, will have been held in Boston, London, Chicago, and San Francisco. . . . In addition to teaching mathematics at the University of Lowell, **Thomas Kudzma** is an accomplished artist. Fourteen of his graphics were recently dis-

Why Technical Experts Don't Always Agree

How can a panel of technical experts fail to agree on the answer to simple technical questions?

Because neither problems nor experts are as simple as we think. Every engineering judgment has two dimensions—technical and philosophical—and the experts bring philosophical baggage as well as technical expertise to all their decisionmaking, says Richard L. Meehan, '61, president of Earth Science Associates, Inc., Palo Alto, Calif., who is also a lecturer in Stanford University's Values, Technology, Science, and Society Program.

For example, consider the situation of utility engineers and U.S. Geological Survey geologists brought together as experts on the question of a nuclear power plant site. "Each 'tribe' brings its own history and epistemology, its own young warriors, its own esteemed elders. . . . Each sees itself gaining or losing territory, often at the expense of neighboring tribes," says Meehan. So the experts end up in disagreement and disarray, the public angry and frustrated, and the principals to the controversy suspicious of each other and of the experts and their motives.

It is such scenarios, observed by Meehan in more than 20 years of geotechnical design and consulting, in which he has specialized on nuclear power plant siting problems, that motivated his new book, *The Atom and the Fault: Experts, Earthquakes, and Nuclear Power* (M.I.T. Press, 1984, $13.95).

Meehan's goal is not to demean the role of the professional—he simply wants professionals and nonprofessionals alike to understand themselves and their motives a little better. He thinks many scientists and engineers are unaware of "the philosophical underpinnings of their own activity"—the fact that "all of us technologists and scientists have some motivation to mix in a little bit of ideology with our observations and continue to call them facts."

But it's also true, he says, that the public misunderstands. "Science was oversold in the 1950s, when scientists became priests who had unique understanding of so-called facts that in fact were not facts at all. . . . There is an excessive faith in the ability of science to adjudicate issues that are fundamentally moral issues." □

played at the University of California Museum in Santa Barbara as part of the Olympic Arts Festival.

On behalf of the class, we offer condolences to the family of **William H. Keating, Jr.**, who died last year, according to a note received by the Alumni Association. At the time of his death, he was a group leader at Draper Laboratories in Cambridge, and lived in Framingham, Mass.—Co-secretaries: **Robert Kaiser**, 12 Glengarry, Winchester, MA 01890, (617) 729-5345; **Caroline D. Chihoski**, 2116 W. Davies Ave., Littleton, CO 80120, (303) 794-5818

The 1984 Bronze Beaver to Elisabeth M. Drake, '58, for her role in establishing the Women's Independent Living Group as well as her part, as a member of AMITA (The Association of M.I.T. Alumnae), in AMITA's High School Visiting Program and Career Conferences. This award recognizes the many ways in which she has brought her industrial and academic experience and expertise to the benefit of the Institute.

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One of the strangest aspects of writing these class notes is sitting here surrounded by the foliage of October, writing words about a reunion in torrid June which will be read in wintry January. Anyway during those days in June it was good to see so many old friends. **George Connor** and his bride, Sue, were there; George has taken over as commander of Pine Bluff Arsenal in Arkansas. . . . Landa and **Dick Hall** were both reuning and picking up son Rikki's belongings. Rikki had finished up his freshman year at M.I.T. and is now well into being a sophomore. . . . June and **Larry Laben** were in from Japan; he's with IBM there. . . . As a long-time employee of the Institute myself, it was a lot of fun to catch up on the goings-on there with Rhea and **Allan Bufferd**, **Frank Perkins**, and others. The Alumni Association was especially helpful. Joe Collins was everywhere helping out. And if it had not been for some impromptu baby-sitting by Marion Redonnet and Dottie Adler, the Stones would not have gotten to the reception with Priscilla and Paul Gray. Thanks again. On Sunday Bess and **Art Collias** hosted a post-reunion, sit-around-the-pool party at their home for the ageing M.I.T.-Boston Latin crowd. Attending with wives in addition to Stone and Collias were **Myer Kutz** and **Barry Weinberg**. A very relaxing way to end the weekend.

Over the summer we heard from **Dick Hall** again. He brought son number two, Jeff, through Ithaca to look at Ithaca College. . . . Bess and **Art Collias** were through last weekend for a visit, too. So if you're ever in the area, give a call.

Classmates in the news recently. **Bruce Blomstrom** was elected vice-president of corporate development and an officer of Whittaker Corp. during the summer. Bruce has served as president of the M.I.T. Graduate Management Association from 1982 to 1984. . . . **Bill Poduska**, whom we also saw at the reunion, has appointed a CEO to work with him at Apollo Computer; Bill will remain as chairman. . . . **Bob Polutchko** has moved up to become president of Martin Marietta Information and Communications Systems, a new unit there. . . . At Upjohn Co. in Kalamazoo, **Chong Y. Yoon** has been named vice-president, fine chemicals. . . . Also this summer Racal Electronics announced that **Ed Cheatam** had been named staff vice-president, corporate communications, for its operations in the United States. Ed will be responsible for the corporation's public relations, advertising, and other communications activities. And at AT&T Bell Labs, **Gil Chin** has been appointed director of the Materials Research Laboratory. Gil has been with Bell Labs since 1962, has authored over 130 papers, and has received 10 patents. Congratulations to all!

Gil Chin, '59

Best in the new year. And remember, to keep reading, you must keep writing.—Co-secretary, **Ron Stone**, 116 Highgate Pl., Ithaca, NY 14850

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Albert Blackwell, a member of the religion faculty of Furman University, Greenville, S.C., has been promoted to the rank of professor. Albert earned his Ph.D. in religion from Harvard and received Furman's meritorious teaching award in 1977. . . . **George Holz** is featured in an article in a Burroughs company magazine. He is a part-time staff consultant and has 34 company patents to his credit, including a gas plasma panel display, integrated circuits, and computer peripherals. . . . **Leland Jackson** has been awarded the 1984 Technical Achievement Award of the IEEE Acoustics, Speech, and Signal Processing Society "in recognition of seminal work in finite word length effects and in the hardware implementation of digital signal processing systems." His family joined him at the society's international conference in San Diego for the presentation.

Alan Kotok is in his 23rd year at Digital Equipment Corp., where he is now a corporate consulting engineer. He manages the Research and Advanced Development Group at Marlboro, Mass. . . . **Jeffrey Speiser** is mentioned in a brochure from the Evolving Technology Institute in San Diego as a lecturer in a short course on advanced signal processing. He is currently at the Naval Ocean Systems Center.—**John E. Prussing**, Secretary, 2106 Grange Dr., Urbana, IL 61801

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In October, I asked whether our classmates would want their sons and daughters to go to M.I.T. I am interested in publishing views on how the M.I.T. experience influenced the careers or lives of '63ers, and whether, therefore, they could recommend for or against it. The pithier and more specific the better, and I will respect requests for anonymity.

Jim Taylor had been interim coach of men's tennis and squash at M.I.T.; he has now been replaced, but remains a part-time assistant coach in both sports. What are you doing with your spare time, Jim?

MITRE Corp., of Bedford, Ma., sends a fancy press release, with a glossy photo, about **Mike Harris**. He is now technical director of MITRE's Naval Systems Engineering Division, at McLean, Va. (I can't publish the photo, so I'll tell you he has a neatly-trimmed beard, wire-rim glasses, and a conservative suit. If you want to know more

you'll have to visit him.) Mike's been with MITRE since 1968, three years after he got his S.M. in E.E. from the 'Tute. His doctorate is from Stanford. Somehow, despite all the book-learnin' and the engineerin', he has found time to get married (his wife's name is Carole), and have five children.

Come on guys and gals. . . . get out your pen, word-processor, stone-and-chisel, or whatever, and communicate. Weddings, bar mitzvahs, first communions, new kids, old kids, paternity suits, earned doctorates, diploma-mill doctorates, ignominious firings, glorious new jobs, Nobel prizes, extra-corporeal experiences, etc. Drop a line.—**Phil Marcus**, Secretary, 2617 Guildord Ave., Baltimore, MD 21218

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Greetings of the New Year! A happy and healthy 1985 to all. Actually, as I write this, it is October 1. Those of us who do business with the federal government are "celebrating" Fiscal New Year—trying to wind down last year's contract and start up this year's contract.

Alumni Fund envelopes bring news from two classmates. **Emma Root** writes that she was sorry to miss the reunion but that she's not overly fond of "overpriced package deals." Her biggest disappointment was losing the opportunity to show off her children. Emma says that she's not preaching these days—child care takes too much time. She sends along a "Hi" to **Martha Redi**. . . . **Barry Pearlstein** is a senior scientist with Hughes Information Systems, developing the "humongous" Command and Control Information System for Northern Europe. He and his family are living in Paradise—that's what Barry calls Irvine, Calif. At the time of his writing, daughter Beth was a senior in criminology at Radford University, son Howard was a sophomore at U.C. Santa Barbara, and daughter Jennifer was a freshman at Woodbridge H.S. in Irvine. His wife, Marlene, is director of medical records at a local hospital.

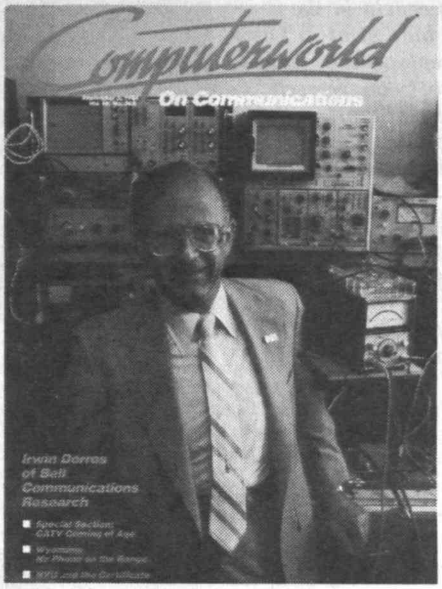
A news release issued by National Information Systems of Cupertino, Calif., announces that **John Enyedy** has been appointed vice-president of sales for the software products division of N.I.S. John joined N.I.S. in 1978 and was most recently their national sales manager. Prior to joining N.I.S., he was employed by Digital Equipment Corp., Velo Bind, Inc. and Tymshare. John, his wife, and family are living in Sunnyvale.

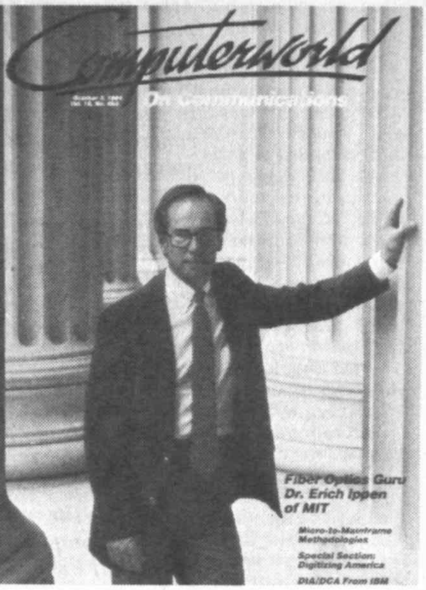
The final news item this month is a sad one. **James A. Lisnyk**, who earned an S.M. in Ocean Engineering in 1964, was killed in a late summer auto accident along with his 14-year-old daughter, Linda Ann. At the time of his death, Dr. Lisnyk was employed by the Naval Sea Systems Command where he had responsibility for the hull design of all U.S. naval ships. Our condolences to his wife, Bridget, and daughter, Amy, who reside in Alexandria, Va.—**Joe Kasper**, Secretary, TASC, One Jacob Way, Reading, MA 01867

65 20th Reunion

About a year ago, I got an invitation from the University of Newcastle upon Tyne to speak at their annual symposium on teaching computing science and to contribute three lectures on provably secure operations systems. A quick review of the calendar revealed that if Anne and the kids returned on Labor Day, we could get a vacation out of the trip. We spent a wonderful ten days touring the Scottish countryside and seeing the end of the Endinburgh Festival. The weather was perfect. If you are in the Boston area and drop by, I can probably be persuaded to dig out the slides from the trip.

After the family returned to Boston, I took the train to Newcastle to give my lectures. Among the European computer science faculty in attendance was **Andy Tannenbaum**. After graduating from M.I.T., Andy went to Berkeley and got a





***The M.I.T. family claimed two covers on** Computerworld on Communications* last fall. On September 5 Computerworld's subject was Irwin Dorros, '56, executive vice-president for technical services at Bell Communications Research, Inc., who was interviewed on Bell's plans for the integrated services digital network—a concept for digital commmunications between major telephone customers and a central office. A month later the cover story was Professor Erich P. Ippen, '62 (right), of M.I.T. This "fiber optics guru's" work, said Computerworld, is "fraught with implications for communications of the future." Ippen's most recent achievement is the world's shortest pulse of light 16 femtoseconds in duration (a trillionth of a second is 1000 femtoseconds)—important, he explained, because to provide ever-higher capacity on optical communications circuits requires ever-shorter pulses of light.

Ph.D. in physics. He then decided he wasn't really interested in physics so he went to Amsterdam to become a computer scientist. (He says the Europeans were so far behind that he hoped they wouldn't notice that he didn't know anything; if the questions he asked during my lectures are any indication, he has remedied that problem.) He is a professor at the Vrije Universiteit, and he has written two widely used computer science textbooks and a number of papers in obscure journals. He has a Dutch wife, Suzanne, and two children, Barbara (6) and Marvin (4). Andy says that he has flown over the Atlantic Ocean 39 times and has been to Africa four times and Asia twice (including an intercontinental boat ride across the Bosporus for $.07). He is going to Australia next month. When he is not abroad or at university committee meetings, Andy likes to bake and cook, and dreams of someday writing a cookbook titled, "How to Prepare your Input."

The news from the Alumni Association is that **Richard Arnold** has been appointed co-chairman for the Tulsa area of the M.I.T. Club of Oklahoma. Richard is with Getty Refining and Marketing in Tulsa, and will serve as state chairman of the club for 1985-86.—**Steve Liener**, Secretary, 6 Midland Rd., Wellesley, MA 02181

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Congratulations to Eileen and *Walter Shedd* of Acton, Mass., on the arrival of son Daniel Patrick. His sisters Diana (13) and Jessica (8) couldn't be more thrilled. Theresa and **Joe Shaffery** are the proud godparents. . . . **Harry Moser** has moved to Kalamazoo, Mich., where he is president of Roto-finish Co., a producer of mass finishing equipment. . . . **William Dietrich** has been elected a special partner of Alex Brown and Sons, a Baltimore investment banking firm.

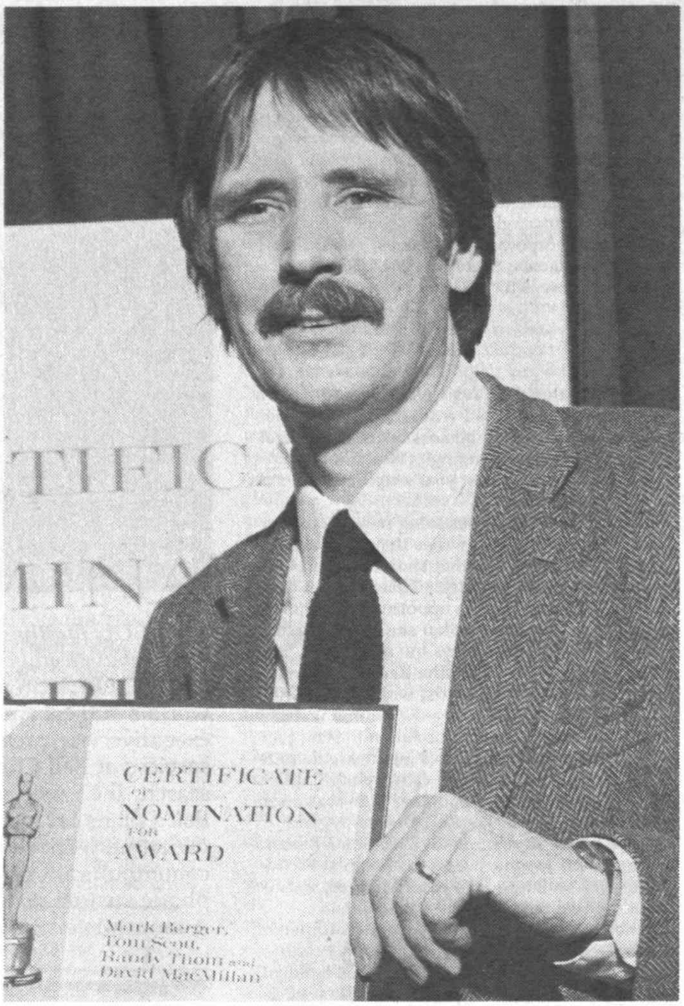
Robert Curd graduated from the Executive M.B.A. Program at U.C.L.A. last June and is now working as a management consultant for Borden Securities in Santa Barbara, Calif. . . . **Eleanor Klepser** has become an enrolled agent, qualified to practice before the I.R.S. Her grades on the 12 hours of tax law examinations placed her among the top 20 in the nation. The Klepsers' daughter, Cheryl, and an Australian girl spent the summer together, with both girls in Pennsylvania for July and in Austria for August. . . . A consistent contributor to this column, **Thomas McDonough**, is under contract to produce his first non-fiction book, "Comet Trek." He'd like to hear from anyone with interesting stories about comets. . . . **Tom Scott** received an Oscar in 1984's Academy Awards Presentation for his part in the sound recording of "The Right Stuff." He is involved in the sound work for "Amadeus."

Martin Melnick and his wife and children have been spending the year in England, where Martin is on assignment at British Aerospace. They have traveled extensively through the U.K. and report that driving on the left now comes naturally. Watch out when they return! . . . My apologies to **Jeff Kenton** for garbling his last message to this column. Jeff points out he was one of ten co-founders of XYVision and not the sole founder of the company. He has since left the company and has returned to consulting in the software field. . . . Nancy and **Ralph Davidson** have moved to

After two years in Venezuela in the Peace Corps followed by a stint in Los Angeles training the replacement group of volunteers, Tom Scott, '66, refused to shave his mustache and work for a concrete pipe manufacturer. A civil engineering graduate, he decided to fall back on his hobbies—music and electronics. Apparently it wasn't a bad decision, for in 1984 he won an academy award (right) for sound mixing on "The Right Stuff."

Other films Scott has worked on include "Apocalypse Now," "Fame," and the recently released "Amadeus," a film about Mozart directed by Milos Forman, based on the stage play of the same name.

While not working on films, Scott works for the microcomputer company, Gifford Computer Systems. "Whether there will be more films than computers in my life from now on I don't know," says Scott. "I'm keeping my options open in true generalist fashion. That is probably the most important thing I learned at M.I.T.—try a little of everything and keep your options open. Thank you, Course I."



Golden, Colo., where he is vice-president of development and technical information for Climax Molybdenum. Nancy is enjoying success as an artist and looks forward to adding images of the mountains to her portfolio. . . . **Roger Koch** at last report was still with Aero Jet Electro Systems in Woomera, Australia. He enjoys traveling and seems to be growing very attached to Australia; he mentions that he is now investing in that nation.

Please remember that the lead time from when you write a piece of news and send it to me until the time it appears in this publication is enormous. The Shedds' baby, for example, will be 8 months old when you read this article.—**Joe Shaffery**, Secretary, 34 Hastings Dr., Ft. Salonga, NY 11768

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Frank March is president of Seaward International, Inc., a leading manufacturer of soft marine fenders and floats. Seaward, located in Falls Church, Va., manufactures a variety of products which permit large ships to berth safely and efficiently, with protection to both vessel and port. Charlene and Frank are enjoying the good life with their two children, Christian, 4, and Philip, 2. . . . **Allen Brown** is a computer scientist at the General Electric Research and Development Center in Schenectady, N.Y. Before joining General Electric, Allen was with Xerox Corp. and was a research associate at Columbia and M.I.T. He received his Ph.D. in artificial intelligence in 1975 from M.I.T. . . . Dr. **Sam Bergman** is an emergency room physician at Cheshire Hosiptal in Keene, N.H. He earned his medical degree from Boston University School of Medicine and lives in Dummerston, Vt., with his wife Irene and son Robert.—**Jim Swanson,** Secretary, 878 Hoffman Terr., Los Altos, CA 94022

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Ora Smith has been with Rockwell International for five years and is currently director of the physics and chemistry department at the company's Science Center in Thousand Oaks, Calif. Beginning in October, 1984, Ora is on a year's leave of absence to work in the President's Office of Science and Technology Policy in Washington, D.C. He will have the position of senior policy advisor on the O.S.T.P. staff, assisting Dr. George Keyworth in formulating national science policy—that is, if the election went as expected in November, shortly after these notes went to press. Ora was selected as the 1985 Fellow from candidates proposed by several of the Industrial Research Institute's member companies. . . . On the "Living" pages of the *Boston Globe* we read of **Michael Albert**'s continuing counter-culture adventures as one of the seven founders of South End Press. The small publishing company was set up in 1976 "as a way to put leftist ideas across," in part due to Mike's difficulty in publishing his first book, "What is to Be Undone." The Press has over 100 titles in print. Although the original communal lifestyle of the Press has now changed to a more traditional working format, S.E.P. is obviously far from conventional publishing. Albert says, "We're not so different from other people. We do the kinds of things normal people do—just not as much." . . . **Charles Guttman** now has two daughters, Rebecca (3) and Lisa (1). He and Ken Rubenstein, '75, are partners in the law firm of Guttman and Rubenstein in New York City. Their firm specializes in patent law, computer law, and high technology law. . . . **Edward A. Parks** is now manager of manufacturing systems in the science products section of Corning Glass, a company he has worked for since 1983.

Catching up on some older notes that came in (that might be a tad out-of-date): **John F. Walters** was recently appointed president of InSpeech, Inc., a speech and hearing pathology service company headquartered in King of Prussia, Pa. . . . **Jeffrey Satinover** writes that after getting a diploma from the C.G. Jung Institute of Zurich in 1976 and an M.D. from the University of Texas in 1982, he is now a postdoctoral fellow in psychiatry at Yale. He lives in Weston, Conn., with his wife, Julie. . . . **Sam Leader** writes, "I now manage a firm that provides custom software for the health claims processing industry. Am enjoying living in the wine country 70 miles north of San Francisco. Have spent my spare time this summer building a barn. Now have two great kids-Fritz (3

1/2) and Genevieve Marie (1)." . . . **M. Ed Jernigan** and family moved into their self-designed superinsulated new house, overlooking the Nith River in Wellesley, Ontario, last May. They are enjoying the country life. Ed is spending his sabbatical working on a new text in pattern recognition and pursuing his research interests in that area as well as in image processing. . . . **John Gruenstein** has been promoted to vice-president and economist at the Federal Reserve Bank of Philadelphia. . . . From sunny Miami Springs, Fla., **Paul deCoriolis** writes, "I've just started working as a research engineer in the electronics group of Condis Corp., a manufacturer of cardiac pacemakers. I enjoy the work and the weather here in Miami, and most of all I enjoy being alive." . . . Major **Ron Bagley** attended the U.S. Air Force's Air Command and Staff College at Maxwell Air Force Base in Montgomery, Ala., and hopes to move to an assignment in Dayton, Ohio. . . . **Peter L. Eirich** and wife Leigh, '70, have a baby girl, Gaia Rose—their first—and they're having a ball with her. They both work for Titan Sytems in McLean, Va., and live in Columbia, Md. . . . **Robert Nordlinger** recounts his travels since graduating: "Completed S.M. in 1970, joined New York office of McKinsey and Co. Transferred to Australia in 1972. Left McKinsey in 1974 as chief executive officer of a large transport equipment manufacturer. Founded own company in 1978—a finance company specializing in vendor leasing for business equipment. Living in Melbourne with wife Angela and daughters Rachel (14) and Julia (13). Hobbies: skiing and flying (own a Beechcraft Baron).

Can't fit any more notes in, except to report that **Rick Barnes** is right down the corridor from me at M.I.T. Lincoln Lab and wants to be remembered to you all. Rick and I both work on polarimetric radar systems, pioneering new ways to tell tanks from trucks without looking at them—quite a trick! Rick recently got his Ph.D. from the electrical engineering department at Northeastern and lives with wife, Sherry, and three daughters in Acton, Mass.—**Eugene F. Mallove**, 215 Highland St., Holliston, MA 01746

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Congratulations to **Walter W. Schroeder III,** who has been promoted to vice-president, Corporate and Acquisition Planning, Midcon Corp., Chicago, Ill.—**R. Hal Moorman,** Secretary, P.O. Box 1808, Brenham, TX 77833

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News is meagre this month! Please send in notes on how 1984 ended great for you and 1985 started even better (or any other thoughts). **Sarah J. "Sally" Simon** has been elected second vice-president of the Engineering Societies of New England. She is a candidate for an MSCE in environmental engineering at Northeastern University and continues to be an environmental engineer at the New England regional office of the EPA.

Apparently some classmates received a blanket invitation to apply for a job at M.I.T. in an administrative capacity, prompting **Mike Wilson** to respond that he is happily employed by the Central Connecticut Regional Planning Agency in Bristol, Conn. as the assistant director. . . . **Gail Thurmond** and her husband Dick Gordon in August had a party celebrating their elegant new deck designed by David Brown, '69. The party also coincided with the first birthday of their cute son Robbie. **Bonnie Kellerman**, back from a great sailing vacation; **Dan Bloom**, on his way to a wedding in Atlanta; **Bob Ebert**, doing great as ever, and finishing up his doctoral thesis at Boston University; Steve Tubbs, '74, starting his own computer company; and Tony Vidmar, '74, were among the friends gathered.

Sadly I have to announce that Bonnie Kellermann noted that in early September **Harvey Baker** died. Harvey had been suffering from a brain tumor for several years. Bonnie is now actively traveling as part of the Educational Council's fall recruiting program.

Recently I had the pleasure of meeting the first female president of the M.I.T. Alumni Association, Mary Francis Wagley, '47. I had lunch with her, Karen Arenson, '70, and Yolanda Yu, '78. Mary is going to make a dynamic contribution this year. Hope to hear from many of you soon!—**Wendy Elaine Erb**, 531 Main St., Apt. 714, Roosevelt Island, New York, NY 10044

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The Alumni Fund offers its sincere apologies to our class for inadvertently printing an incorrect listing of '74 associate agents (home-based telethon callers) in this year's annual report. (The list of other committee members is correct as printed.) Following is the correct list: **Kristine L. Andersen, Yee Wah Chin, Frank A. Gulla, Richard A. Hartman, Barry N. Nelson, Neal D. Ryan, Marko M.G. Slusarczuk,** and **R. Gregory Turner**. The Alumni Fund thanks each of these volunteers for their help in making our reunion gift an overwhelming success.

The first and only letter this month comes from **Paul Mailman**. Paul really and truly sent me his life story as he promised. We are going to publish it in installments. Paul writes: "I'd gotten married in 1975 to Deborah Ruppert, Michigan State, '74. We'd met in April 1984 when I went to Michigan State University over vacation to visit a mutual friend. By 1980 Debbie and I decided to start a family. We then discovered that it wasn't as easy as we'd been led to believe. (Medical details for any doctors in the house: two ectopic pregnancies requiring surgical removal of both fallopian tubes. If anyone else tells me a 'gee, I knew a couple who couldn't have children for years and as soon as they adopted they got pregnant' story, I may scream.) We began adoption proceedings in 1981.

"After incredible amounts of red tape (medical statements, financial statements, fingerprints, a consulate seal that verifies that the state seal that verifies that the notary seal that verifies that your signature is valid is valid), money (don't ask), and time (elephants do it faster than this!), our little wonder arrived in September 1983. Eduardo Ruppert Mailman ("Eddie" to the gringos) arrived from El Salvador with a smile on his face, excitement in his eyes, and a song in his heart. Having my first Father's Day with him was great. Parenthood is far from easy—we've had our share of temper tantrums, spilled juice, sulking and whining, and rushing off to the emergency room (fractured collar bone a couple of months ago). But folks, if you've got the love in you heart to give, the rewards are worth it. As his third birthday approaches next month, he is confident that he will be getting a bicycle that we saw in a bike store a couple of months ago. Debbie and I insist that we haven't made up our minds on it yet. Right. Ya think maybe he's gonna get it?

"Debbie and Eddie and I are currently living in Maynard, Mass. along with four cats, a dog, a tank full of fish, and numerous houseplants, all of whom have kindly consented to sharing their space with us. The house is a bit cramped but has been a good 'starter' for us. We hope to move to more spacious quarters, but it's hard to tell when the opposing forces of our finances and the economy will let us." . . . I will save the rest of Paul's letter for my next turn at writing class notes."

All other class news this month comes from **Richard Sternberg.** He writes, "I am your new adjunct assistant to the class co-secretary assigned to writing class notes for those of you who would either prefer to send your mail or telephone calls to the capitol of our nation, rather than the hub of the universe." . . . **David Burnstein** is still, after nine years, working for TRW in Redondo Beach, Calif. He is steadily moving up the corporate ladder while he continues to enjoy the California sunshine. Dave continues to sail and to race whenever he has a chance, and for the past four years he has lived in a tastefully furnished condominium high above Santa Monica Bay. . . . Two of our classmates I see quite frequently in the Washington area. **Ed Chan,** who majored in Course VI and then went on to the University of Maryland Medical School, is now an orthopaedic surgeon with the Capitol Area Permanente Medical Group, primarily practicing in Landover, Md. Ed moved to the Washington area in 1983 after spending five years in the orthopaedic residency program at New York Medical College in Valhalla and Manhattan. He recently returned from a one-week course in Central, Maine, which especially in the summer, may be one of the most pleasant places on the East Coast to get away to. . . . **Bob Brooks,** after finishing in Course VIII and then going on for his Ph.D. in theoretical physics, did what many doctoral students in physics have been doing over the past ten years—copped out and went to medical school. Bob has just recently finished his first year of residency in the orthopaedic surgery program at Georgetown University and is currently at Children's Hospital in Washington, D.C.

Since last appearing in these class notes nine years ago, I have performed the following feats. I got engaged. (I actually went through with it and got married.) I graduated from medical school (1978) and moved to New York to start a five-year residency in orthopaedic surgery. My wife and I became separated (1981) and subsequently became divorced. I moved to Washington, where I took a job as an orthopaedic surgeon with a large health maintenance organization. I quit my job and went into the private practice (and now I know why they call it practice) of orthopaedic surgery in the northern Virgina suburbs of Washington. Right now I am having a great time practicing what is euphemistically called private medicine and I am looking forward to moving into a typical suburban colonial home in Vienna, Va. I have joined the M.I.T. Club of Washington to which I dutifully pay dues but never attend any meetings, and keep on the lookout for people wearing Brass Rats, in as much as they tell me there are over 2,000 graduates in the greater Washington area. I sincerely hope that all those people who promised to write me letters at the reunion will do so along with any and all the other members of our class, and I especially hope that those of you in the mid-Atlantic region will either drop me a note or give me a call or just show up in the office some day."—**Richard J. Sternberg,** M.D., Northern Virginia Orthopaedic Clinics, 2500 N. Van Dorn St., Alexandria, VA 22302, (703) 578-1300; **Lionel Goulet,** 21 Melville Ave., Dorchester, MA 02124; **Jim Gokhale,** 45 Hillcrest St., Arlington, MA 02174

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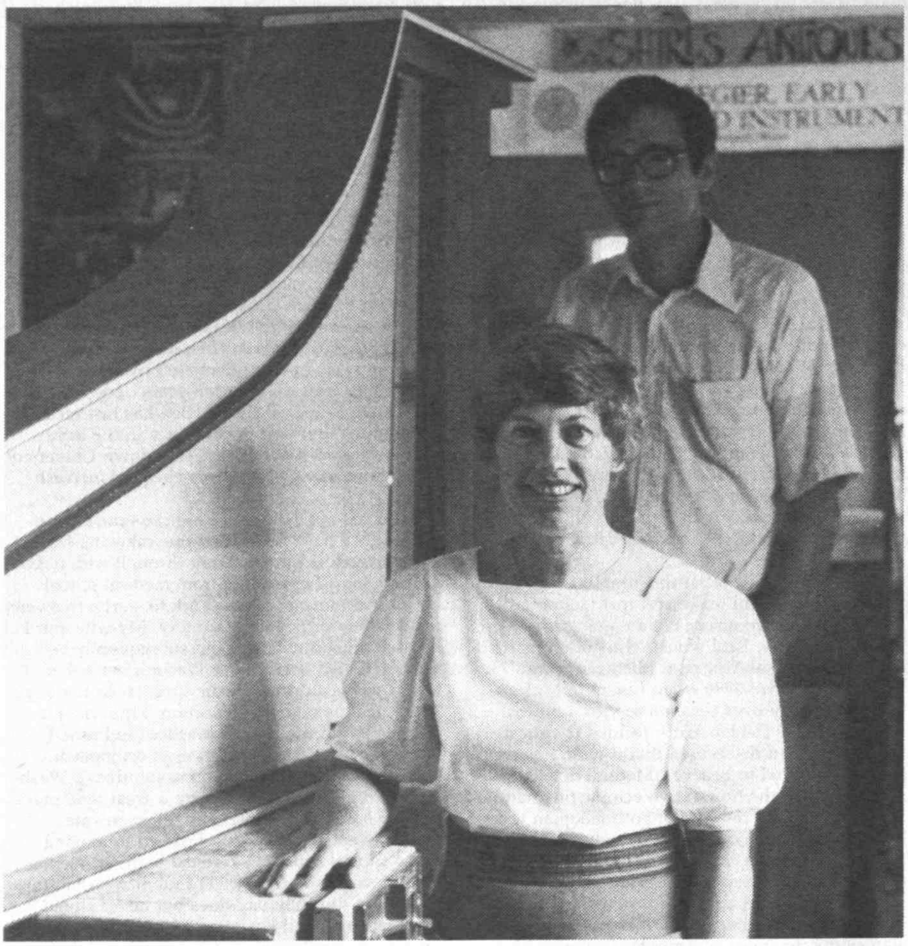
The mails have not provided very much news. So, please write! From **Joseph Abeles:** "I'm now doing research in high-speed eletronic devices at Bell Communications Research following the breakup of Bell Labs into AT&T Bell Labs and Bell Communication Research." . . . **Hilary Morgenstern** received her doctorate of optometry from the New England College of Optometry in March 1982. . . . **James Miller** is now back at the 'Tute working towards a Ph.D. in artificial intelligence. He has been awarded a grant supported by funds from Wang Corp., from the American Electronics Association's Faculty Development Program. It includes tuition, fees, and stipend which, given the 'Tute's lofty tuition level, makes for a nice award. Congrats!

Jeff Mitchell writes: "A year ago I left the Navy—I had just finished two years as captain of a ship and they couldn't offer me anything I liked. I'm working for McDonnell Douglas at the Kennedy Space Center in the Horizonal Cargo Processing Branch. What we do is assemble and test the Spacelabs. I was recently promoted and



They're a team—she plays the harpsichords he makes. After graduating with a degree in engineering, Rod Regier, '72, gradually turned a part-time interest into a full-time occupation. His wife, Shirley Mathews, recently cut an album of fortepiano music played on a replica of a Viennese fortepiano of the type used by Mozart around 1800. Regier copied the instrument from an original made by Anton Walter of Vienna.

"Intellectual and musical curiosity" is how Ms. Mathews sums up her interest in reproduction instruments. "We want to know what Mozart and Beethoven had to work with." (Photo: Roger Brown)

am now in charge of the testing at the Orbiter Processing Facility (OPF). We write and run the test procedures for the Spacelab from when it moves into the Orbiter till launch. It's quite exciting and the launches are spectular. Several M.I.T. folks have visited for a launch—most notably, Ed Hunter, '79. Anyone who remembers me and wants to watch a launch—write! . . . Life is fun and busy. I'm working on the master's in space technology at FIT. It's really space engineering, but the hard core engineering department won't let them change the name. I'm flying (not too often) and teaching ground school. Twice a week I play volleyball in the warm sunny Florida weather, although we'll have to stop when the time zone changes since we play after work. . . . Life is really rough. If anyone's coming to Florida and knows/remembers me, have them give me a call (305) 773-4381."

As these notes are being written (October), Rita and I are in the midst of our move to Forest Hills. I have developed quite a bit of practice moving, it seems, both fiscally and physically. The currency and metal markets continue to make sporadically gut-wrenching moves. Cocoa is creating premature grey in certain circles. As for your secretary, he is aside, not trading. Instead, I am still looking at the pencil business in the bowery! On a slightly more serious note, I am looking at other areas, and if anyone has any start-up ideas in New York City, I would enjoy exploring them.—**Arthur J. Carp,** Secretary, 110-07 73rd Rd., Apt. 6F, Forest Hills, NY 11375

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Deborah Stutman wrote a long chatty letter, describing life since graduation. Deborah has completed her Ph.D. at Lehigh University, doing work in emulsion polymers, like latex paint, and is now working for Owens-Corning Fiberglas in Granville, Ohio, and living in Columbus, Ohio. Deborah says she will now be working on materials like asphalt, "from one color extreme to another." She presented her research at the summer meeting of the AIChE in Philadelphia. Deborah recently saw **Kenneth Sun**, who was visiting his family in Columbus and proudly displaying photographs of his two daughters. . . . **John Farrell Peternal** was ordained a priest on May 31, 1984, in Rome, by Pope John Paul II. John spent a year after graduating in Course XV working with Statler Industries, and then a year teaching in Concord, Mass. He studied theology in Rome and received his Ph.D. from the University of Navarre, Spain. John was ordained in the Prelature of Opus Dei, and expects to be back in the United States by the end of 1984.

While on a business trip in New England, I managed to stop by M.I.T. for a bit, and saw **Chris Wang**. She and her husband, Norman Sheppard, '78, were married in 1980 and had a daughter, Sarah Elizabeth, in August this year. Chris received her doctorate in January and is finishing up her postdoctoral work at M.I.T. now. Chris and Norman have bought a house in Bedford, Mass., so she is all set to begin work at Lincoln Labs in November, continuing her studies in crystal growth. That's all the news for this month. Please write soon—**Barbara Wilson Crane**, Secretary, 6431 Galway Dr., Colorado Springs, CO 80907

78

Good evening and Happy New Year. This is your class newshound reporting with your class news. The Olympics—remember the summer L.A. Olympics? *Tech Talk* reports that several M.I.T. athletes competed in the Olympics—most notably, our classmate **Mark Smith**. Regular readers of this column will not be surprised to learn that Mark was a member of the U.S. fencing team (which finished fifth in the team foil competition). Unfortunately, there is no light-weight crew competition in the summer Olympics; however, if there had been, M.I.T. would have had three members on the men's eight, including "classmate" **Seymour Danberg**. (Seymour started with '77, but we'll take him.) It's interesting to note that Seymour did not start rowing until he was a graduate student, so he's come a long way in a very short time.

Only one boring postcard this month . . . this one is from **Julie Kozaczka,** who sent me a picture of an 1890 underground—ahem—W.C. Jule is still living in Watertown, Mass. and reports that she is looking for a change in career ("I don't *wanna* be an engineer, not *nohow!*") and a new band. She writes: "Do you know off any hot, imaginative guitar-synthesizer aces who hate Elvis Presely but love Andy Summers, Adrian Belew, Laurie Anderson, and Randy Newman? If you do, let me know. It could be magic." We'll keep our ears open Jule. . . . **Mitch Hollander** reported to me about a couple of weddings that took place last spring. Dr. **Yvonne Tsai,** married Scott Kukshtel, '79, on the last weekend in May in New York City. Present from the class were Mitch, **Mike Mitsock, John Richardson,** and **Ursula Wolz**. The next weekend, Ursula decided to get into the act . . . also in New York City, she married Jim Dunne on the first weekend in June. Yvonne couldn't make the wedding—she and Scott were still on their honeymoon—but present to represent the class were **Paul "Malfo" Malchodi** and Mitch.

Meanwhile, back in Cambridge, Mitch is still working for DuPont as a research and development chemist, and is planning to go back to school part time for an M.B.A. On the side, Mitch is stage manager of a local production of *The Deadline*, a play being produced by the Mirror House Group. Mitch's roommate **Rich Zingarelli,** continues to work as an engineer for the Army Corps of Engineers, but he's currently in a training program in Washington, D.C. Their other roommate, **Mike Geselowitz,** continues in his long travail as an archeology grad student at Harvard.

I ran into **L. Zaurie Zimmerman** on the Red Line the other day. Zaurie is working for a Boston real estate developer in downtown Boston, and seems to love it. . . . **Phil Klenn** writes that he has left his position as a metallurgist with DuPont in South Carolina and has begun medical school at the University of Kentucky. . . . **Janet Freeman** writes that she just finished her master's in aeronautics at Caltech, and she's going on for her engineer's degree under a Hughes Aircraft Fellowship.

And then there's me. Yes, there is life after the law—I am getting happier each day about my decision to leave the practice of law (at least temporarily). However, my new employer, Blue Cross, may not survive the transition. Other than that, not much news on the home front, but I would like to make the following comment. Contrary to the opinion in some circles, I do not (often) make up the news that I report. Please, please send me some news—in a letter, a postcard (boring or otherwise), a phone call, or any other form of communication (be creative). It doesn't have to be clever or thrilling or even true. All it has to be is sent to me. WRITE!—**David S. Browne,** 50 Follen St., No. 104, Cambridge, MA 02138, (617) 491-5313 or work 956-2214

79

Happy New Year to all. On behalf of the class of '79, I wish you all a healthy and happy 1985.

Patrice Tyrell, who finished her Ph.D. in chemistry at Yale this past summer, is now working for Intel Corp. in Portland, Ore. . . . **William Kleinman** is practicing law in Dallas with the firm of Haynes and Boone, and was planning a September 1984 wedding to Lisa Oppenheimer. . . . **James Atwood** is getting a degree from Northwestern University's Kellogg School of Management. He spent the past summer in Chicago working for the consulting firm of McKinsey and Co., and is studying this fall in Delft, The Netherlands. . . . **Walter Glomb** is working on electro-optic systems at United Technologies Research Center. He writes, "I've been happily married three years, and enjoying our son, 18 months old and showing us a whole new world!"

Jeffrey Burrows just finished his M.S.E.E. at Stanford. He's now working at Lincoln Labs while his wife, Julie, attends Harvard Business School. . . . **Janet Metsa** left Eastman Kodak in Rochester, N.Y. and spent four weeks bicycling in England and France. She is presently working for the EPA in Research Triangle Park, N.C. . . . **David Tuckerman** received his Ph.D. in electrical engineering from Stanford in February, and is now on the staff of the Lawrence Livermore National Laboratory in California. . . . **Guy Emanuel** graduated from Cornell University Medical College in May 1983, and completed his internship at Downstate Medical Center, Kings' County Hospital in internal medicine and pediatrics in June 1984. He will continue as a resident until June 1987.

Stephen Boos got his M.D. from Columbia in June 1983 and is now a pediatrics resident in the air force at Travis AFB. He was recently married to Kit Sang Leung of New York. . . . **Peter Kramer** writes, "I just bought a house across the street from the Gulf of Mexico. The Tampa-St. Pete area is beautiful. I'm now working as manager, material development and production, for University Optical Products Co. in Largo, Fla. Will soon be windsurfing before and after work each day. Any old classmates in the area, give me a call. I've got plenty of room. The phone number is (813) 393-2772." . . . **Mimi Fuhrman**, whose activities were mentioned in last month's column, wrote with more details about her wedding. "I got married in January to Dimosthenis Kaleas, a mathematician/computer scientist. We're planning a month-long delayed honeymoon in Greece. **Mary Haselton** attended the wedding. Where are all the other geologists from our class!?"

Joe Rice wrote a nice long letter this summer. "I just returned from 15 months of traveling abroad. Seven of those months were spent in Nepal, and two were spent with **Jimi Parks**, who will be finishing a 27-month stint with the Peace Corps in December. Jimi lives in a village called Melung which is a tough day's walk from the nearest 'road.' He's teaching science and mathematics to sixth and seventh graders. Life in Melung is quite spartan—no electricity, no telephones, no newspapers, no heat in the winter, and nothing to eat but rice and lentils. On the other hand, there aren't any cars, very few day-to-day tensions, and life in general is peaceful and balanced. Plus the view of the Himalayas is spectacular. After returning from my travels, I've moved back in with **Claude von Roesgen**, **Marc Zeitlin**, Calvin Hsia, '80, and Dave McAllester, '78 on Burnside Ave. in Somerville. Claude is actively pursuing a career in film/video. Last summer he went to the Pyrenees and filmed a Boy Scout expedition to Mount Perdido. Currently, he's running a company called Burnside Productions and also working part-time at BFVF (Boston Film and Video Foundation). Marc will soon be flight testing the home-built airplane he has been building for the past two years. He has also started a company called Burnside Aerospace and consults with people who are building and/or designing home-built airplanes." Thanks for all the information, Joe.

A letter from **Gordon Haff** from last summer: "I will be back to school in the fall at the Cornell Graduate School of Management for an M.B.A. No other M.I.T.ers there, although Dave Copeland, '81, will be working for IBM nearby. I'm still chairman of the *Dartmouth Review* and still do 'the last word' column of quotations. I'm also still compiling a monthly political quotations column for *Conservative Digest*. I've just started getting everything packed for the move. I'll be leaving ODECO at the end of July and then am going to Kenya with my family for a couple of weeks in August, and then straight to Ithaca."

I have some more information about **Stephen Holland**, who died on September 11, 1983. His sister, Anna, writes that "Stephen Daedalus Holland, 30, was injured in a motorcycle accident on September 9, 1983, in California, and died two days later at the University Hospital in San Diego. Stephen got his bachelor's degree in mathematics. He had moved to San Diego in March 1983 to work as a systems programmer for the research firm of Global Analytics, Inc. Stephen was also known in the Boston area as an accomplished guitarist who played in several area bands. He invented and patented an infinite sustain device for the electric guitar. As music was his first love, a scholarship is being set up at the Berklee School of Music in his name. Stephen was cremated in San Diego. A memorial service was held on October 8." Stephen's father was Alfred C. Holland, '53, and his grandfather, Warren S. McCulloch, worked at M.I.T. for many years in cybernetics. Our sincerest sympathies go to Stephen's family.

Hank Rappaport writes, "I finally graduated from Jefferson Medical College last June, and have been released from my prison sentence in Philadelphia! I'm now living in Fresno, Calif., raisin capital of the world, where I'm doing my internship at a VA hospital. Things should be looking up, though, next year, when I'll most likely begin work at Hewlett Packard's research labs in Palo Alto, designing computer systems for patient care applications. Let the gang know they have a place to visit on their travels between L.A. and San Francisco. Yosemite's right nearby, too. Sorry I couldn't make the reunion, but I had a great time seeing all of the Theta Chi gang last May." . . . **Bob Gompf** just got his Ph.D. in math from the University of California, Berkeley, and is now at the Mathematical Sciences Research Institute in Berkeley, where he will continue his research in four-dimensional topology under an NSF post-doctoral research fellowship. After that, he plans to accept a three-year assistant professorship at University of Texas, Austin. . . . **Richard Meinig** got his M.D. from the University of Texas Health Science Center at San Antonio last May. He is doing an orthopaedic surgery residency at the University of Colorado.

As for yours truly, I have exactly 12 days of singledom left before I tie the knot with Robert Lustig, '76. Planning a wedding is such a delight—for those of you are still single, take my advice and elope!!! More next time on the big event itself, which will be attended by many M.I.T.ers. Till then—**Sharon Lowenheim**, Secretary, 303 E. 83 St., Apt. 24F, New York, NY 10028

80 5th Reunion

Greetings from the 19th hole. Since receiving my M.B.A. from Harvard this past June, I relocated to Reading, Pa., spent a week at Club Med in Martinique (highly recommended as a socially decadent form of rest and relaxation), and then began a consulting position at a small firm called Strategic Analysis, Inc. Strategic Analysis specializes in business consulting to companies in the specialty materials and chemicals industries. Because the work is both a service and project-oriented, the position is an interesting one—more often than not, one has to become an expert in a given area virtually overnight. Other than the fact that I am no longer in San Francisco, I have no major complaints. On the other hand, the cost of living in Reading is very reasonable. My neighborhood has its own golf course, among other things. And I have been known to frequent its 19th hole more often than the other 18. . . . Imagine my surprise when, while interviewing at Strategic Analysis, I ran into **Jeff Tyrrell**. Jeff and his lovely wife, Marianne, were last seen headed for Texarkana, Texas, where Jeff took up a position with International Paper in one of their plants. Three years and two adorable daughters later (Tiffany and Jamie), Jeff and his family moved back to their hometown of Reading, Pa. Jeff joined Strategic Analysis and has since been promoted to project leader. The Tyrrells live on a farm, complete with goat and a home with parts dating back to the early 1700's.

The mailbag for our class was rather light this month. I hope this means you are all leading active and busy lifestyles, and more importantly, saving your news for our fifth reunion this coming June. Mark your calendars. I hear **Frank Wojtowicz** is planning some great activities.—**Debra A. Utko**, Assistant Secretary, 18A Congressional Circle, Flying Hills, Reading, PA 19607

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Dino Rinaldi writes, "I've been stationed at Eglin A.F.B. since graduation with 14 months to go. Lots of sun and beaches. I've earned an M.B.A. by taking night classes and have co-founded a firm, Avatar Electronics." . . . Dino kindly sends news of other classmates: Lynda and **Guido Defever** just celebrated their third wedding anniversary and are currently contemplating additional family members. Guido is doing well at Rocketdyne. . . . **Janus Ternullo** is in the Washington, D.C. area, working for the Naval Surface Weapons Center. He still longs to become a rich and famous drummer in a band. . . . After finishing his master's in mechanical engineering and then traveling around Europe for many months, **Ed Glassman** moved to White Plains, N.Y., to work for I.B.M. designing robots. . . . **Steve "SMATIB" Keith** is still at the Air Force Institute of Technology near Dayton, Ohio, struggling for his master's. . . . **Bill Shelton** is working near Dayton at the Air Force's Foreign Technology Division.

A nice phone call came today from **Lynn Radlauer**. Lynn, who will be finishing up her M.B.A. at Harvard this year and will be returning to Bain and Co. in Boston, reports that **Therese Prisby** will be getting married soon and is currently in Chicago. Lynn herself will be married this June to

Ed Lubell, who's from the Manhattan area. Lynn also reports that **Evelyn Jacobson** is doing fine, and that **Julie Neuringer** has finished medical school and is beginning her internship. . . . **Bruce Kirch** reports that he graduated from General Electric's Manufacturing Management Training Program in June, 1984; currently working as a quality control engineer at G.E.'s Aircraft Engine Business Group in Lynn, Mass. . . . Heartfelt congratulations to **Josh Littlefield** and his wife, Suzy, who are expecting a child at the end of March.

The other day, a man sitting next to me on an airplane noticed my brass rat. He frowned and asked, "What *is* that rodent on your ring?" He thought it meant I belonged to some secret society. After this past month's mail, I'm beginning to think he may be right. In other words, *write!*—**Chuck Markham**, Secretary, 362 Commonwealth Ave., #2E, Boston, MA 02115

83

Happy New Year fellow members of class of '83. I hope you have all enjoyed your holidays. I almost feel back in the swing of things since my return from Europe. I arrived from Paris on September 9 at 11:30 p.m.; I was at work September 10 at 8:00 a.m. to start my marketing job in IBM's New York Finance Branch on Wall Street.

This issue includes several month's news. **Chester T. Barry** is currently working towards his M.S. in chemical engineering at Lehigh University, supervised by M.I.T.'s football superstar **Harvey 'Hollywood' Stenger**, who obtained his Ph.D. in Course X in 1983. Chester says he'll be here for spring weekend and looks forward to seeing all his friends. . . . **Bruce Calder** is assistant vice-president at Citicorp. . . . **John Weinert** says he is one of the big boys at Schlumberger, working as a field engineer based in Bombay, India.

Cynthia Bedell writes that she is a smoke platoon leader for the 164th chemical company at Fort Lewis, Wash. Cynthia completed her officer's basic course last October in the Mojave Desert. She is in touch with John Bernays, '79, but there are no other M.I.T.ers in the area. Cynthia says she has found a softball team but is still looking for a rugby team; in the meantime she keeps busy by playing flag football. She sends a good luck message for M.I.T.'s rugby team's upcoming season. . . . **Mark Fenton** is in the limelight: he qualified for the 50 km race walk. Mark continues his research at the U.S. Olympic Committee's Biomechanics Laboratory. The Lab emphasizes improving an athlete's performance through visual imaging with high-speed video cameras. . . . **Mark Schaefer** competed in the World Lightweight Rowing Championships held in Montreal last August. Mark was Number 3 man in the men's eight.

Monica Alcabin writes a letter telling of her travels, and reporting news of many classmates. After leaving M.I.T., Monica went to California to work for NASA/Ames Research Center in Mountain View. She was accepted into Stanford's engineering economic systems master's program and will attend part-time. Monica competed in last year's Boston Marathon, finishing in a time of 4:16 and beating Boston Mayor Ray Flynn. . . . **Dave Bauer**, **Bruce Cambell**, and **Bob Foss** and his wife, Felice (Wellesley '83), are all working for Martin Marietta. . . . After a day of wine-tasting with **Michele Devereaux** and Monica in Napa Valley, **Mark Contreras** admitted to working for GenRad in San Jose, and **Jim Holderle** confessed to working for Hughes in Los Angeles. . . . Monica reports the rumors that **Henry Benson** is working for Teradyne in Boston and **Jay Caplan** for Xerox in Los Angeles. . . . **Robin Hoe** survived her first year in Columbia Medical School. . . . **Joice Hiwiawan** will be back at Tech for another bachelor's in architecture this spring, after she returns from studying in Vienna. . . . **Javier de Luis** is still at M.I.T., working towards his masters in aeronautics and astronautics. . . . **Dave Salminen** is working for Pratt and Whitney in East Hartford, Conn. . . . **Claire Jalbert** works in Connecticut for a plastics company. Thanks for the update, Monica.

Sargeant **Jeffrey Johnson** was recently decorated with the Air Force Achievement Medal at Pease Air Force Base in New Hampshire. The achievement medal is awarded to airmen for accomplishments, meritorious service, or acts of courage. The letter did not say for which area Jeff received the medal. Congratulations, Jeff. . . . **Akwete Akoto** and **Laverne Gibson** sent me a post card from St. Louis, Mo. Akwete says he has recently returned from Ghana, West Africa, and is now working on developing material handling systems for Federal Express Corp. in Memphis. It seems as though Akwete ran into Laverne at an M.I.T. Alumni Association float trip in St. Louis. Laverne and **Brenda Kitchen** are currently attending Washington University Medical School. It sounds as though Laverne and Brenda are having a wonderful time. Thanks for the card!

Our celebrity '83 of this issue has to be **Heidi Tocker**. Heidi sent me a letter from Thailand. Heidi started work for Malcolm Pirnie, an environmental engineering firm in New York. Heidi left her job to join the Peace Corp. She now works as a water resource engineer in Udornthani (about 40 miles south of Vietiane, Laos). She is currently living with a Thai family and is studying Thai and Chinese. Heidi says she does not get a lot of mail and welcomes anyone to drop her a line. Her address is: Salaklang, Amphur Muang, Udornthani, 41000, Thailand.

Kathleen Harigan '84 works two floors above me. Kathleen said she attended the wedding of Katja and **Mark Seidel** this past summer. She said the wedding was beautiful and Katja and Mark were extremely happy. Kathleen also said she ran into **Eric Johnson** at the wedding. She claimed that Eric has been keeping a pretty low profile due to his slanderous remarks in past issues of the *Review*. His obnoxious remarks were aimed directly at M.I.T. coeds. Kathleen said she had been waiting a long time time to confront this spineless Chem E. I suppose there are a lot of coeds out there who would love to get their hands on Eric. Kathleen says she has already begun preliminary efforts in establishing a New York chapter of the "I Hate Eric Johnson Fan Club." All interested individuals should write to Kathleen.

I have been temporarily staying with Martin Kannengieser, '83. I have to go to Atlanta and Dallas for two months so I figured if I could survive until class I wouldn't have to hunt for an apartment until January. I imagine while you are reading this article I am once again homeless. At least my thesis is out of the way. Take care and don't forget to drop me a line. I am always looking for celebrity '83 material. If you think you should be in the spotlight, then write in 25 words or less why you should be.—**John E. De Rubeis**, Secretary, 47 Gillette Ave., Sayville, NY 11782

84

Salutations! I hope the holidays have been joyous and that the coming year proves to be productive, prosperous, and happy for all of you (especially those who read my column regularly). Though it is still September (and not even autumn) as I write this column, I feel as if I am starting a new year; I guess that since I am still a student, the first day of classes is effectively the beginning of a new year.

R/O Week went well this year. I saw quite a few '84ers back for rush. In fact, the Institute R/O committee included the likes of **Kathy Chamberlain** (R/O coordinator), **Mike Goulding** (events coordinator), **Todd Strauss** (picnic coordinator), **Mark Radlauer** (IFC liaison) and myself. Mr. **Bill Maimone** returned as IFC chairman and gave what I considered to be a most inspiring speech during the Freshman Picnic.

I also ran into two frisbee tossers from Kappa Sig, **Niall O'Driscoll** and **Joe Parker**. Niall told me that he spent the summer doing some work for his thesis advisor and that he will be attending graduate school in mechanical engineering at Columbia in the fall. Joe told me that a recent front-page photo in *The Tech* "showed only half the kegs" Kappa Sig had consumed that week.

I was surprised to cross paths with **Sabrina Lewis** this fall. Sabrina is working as a process control engineer for the Foxboro Co. in (of course) Foxboro, Mass., but is living in Cambridge. I walked Sabrina home and discovered that she is rooming with **Cheryl Whiteman**, who is working for Procter and Gamble in Quincy, Mass. . . . It is rumored that **Barry Surman** has risen from his ignominious position as an editor for *The Tech* to become a reporter at the city desk for the *LA Times*. I just wonder how Barry can meet copy deadlines when he had problems getting his thesis done on time; maybe the *LA Times* gives incompletes.

I received notice from **Sandy Champion** that she and **Jeffrey Whaley** were married June 9, 1984. She adds, "We are each working on an M.S. in mechanical engineering at M.I.T." I guess having a common interest is an important prerequisite for a good relationship. Congratulations, Jeff and Sandy. . . . At Toscanini's, I bumped into **Dennis Sacha**, **Brett Hildebrand**, and **Jeff Yoon**. During this mini-reunion, we exchanged gossip and I realized that my last column's feature on Bakerites was missing some very important information. First, **Ann Classen** is now working for the Department of Transportation in Boston and changed her name—to Mrs. **Jeff Berner**! I talked to Jeff in July, and the bum didn't even mention that he was getting married (probably because he didn't want me to crash the wedding reception). Well, congratulations anyway! . . . Dennis further informed me that **Diane Peterson**, our lovely class president, had been invited to the wedding (Sacha knows how to rub it in) but missed it because she had to help launch the space shuttle. Dennis elaborated, "I think she watches a monitor." . . . **Leif LaWhite** is a TA for 6.071. . . . **Chris Craven** is employed by Combustion Engineering (according to Dennis: "I think they do laser welding") and is living with Eric Olsen, S.M. '83, and "Andy the hot dog man."

As the reunion broke up, I asked Brett and Jeff (both of whom had been exceptionally quiet) what I should mention about them in my column. Brett explained that he was finishing up his thesis "in New York." Jeff told me that I should mention that he just received the Nobel Prize; he didn't elaborate as to what field he received it in. . . . I was surprised to find two '84ers in one of my classes this term: **Lloyd Hey** and **Eric Alani**. Lloyd is in the HST program, happily attending medical school classes. He helped out with Theta Delt's rush this year (apparently TDC, in an attempt to change its image, is now calling itself Theta Delts). Eric is attending graduate school in biology "up the river" (Harvard) and is taking 7.73 "to make life bearable."

I received a very "personal" letter from **Ken Zeger** recently. He writes, "This summer, following graduation, I took off and drove around the country and thru (sic) Canada, backpacking and mountain climbing in the West. I will be getting married this June to Donna Farber, currently finishing up her senior year at U. of Michigan. We have known each other since age 12. In January, we will be starting graduate school together at U.C., Santa Barbara. I'll be in course 6 stuff; she'll be in microbiology. I've been swimming about three miles a day in my spare time."

I'd like to point out my new address. I'd also like to mention that I am pleased that my column has been consistently the longest column in the class notes section; keep that gossip coming. However, Sandra Knight, the editor, has complained about my columns exceeding the space limitations. She's even threatened to cut me off in mid

—**Peter Tu**, Secretary, 362 Rindge Ave., No. 19B, Cambridge, MA 02140

Medal of the (UK) Institute of Acoustics. . . . Associate Professor **J. Kim Vandiver,** Ph.D.'75, was appointed to a three-year term as director of the M.I.T. Experimental Study Group (ESG) last July 1. The ESG offers an informal, unstructured educational opportunity to a limited number of freshmen and sophomores (*see* Technology Review *for November/December, pages A-18-A21*). . . . **John A. Livingston,** '41, writes, "After my graduation from M.I.T., I worked for the Bethlehem Steel Co. in the Shipbuilding Division, Quincy, Mass., until 1946. At that time, shipbuilding in the U.S. seemed to be entering another post-war slump. For this and for personal reasons, I decided to get out of the industry. We moved to Connecticut and I took a job in a consulting mechanical engineer's office. My M.I.T. education proved to be sufficiently broad so that I was able in 1948 to take (and pass) the Connecticut Professional Engineer Exam in mechanical engineering with a little study. Since I was then a landbound engineer, my outlet for many years became sailing and coastwise cruising. I finally gave that up about 15 years ago and turned to building and operating 'live steam' locomotives and trains and small marine steam engines. I have been happily retired since 1977."

Assistant Professor **Dale G. Karr** spent last summer working at the David W. Taylor Naval Ship Research and Development Center under the navy's exchange program for university professors. Karr was also recently awarded a Research Initiation Grant by the National Science Foundation.

Captain **John W. Crawford, Jr. (USN, Ret.),** S.M.'46, writes, "After leaving M.I.T. in 1946 (Course XIII-A), I returned with my classmate **Edwin Kinter,** S.M.'46, for a master's degree in physics before entering a long tour in the Naval Nuclear Propulsion Program. Retiring from the Navy, I then spent another long tour in the government's civilian reactor development program (AEC, ERDA, then DOE). Retiring in 1981, while deputy assistant secretary for nuclear energy, I am now a management consultant on nuclear energy."

The fourth annual Robert Bruce Wallace Lecture was held on October 29, 1984 (postponed from last April). Dr. Bertram Herzog of Herzog Associates spoke on "New Directions for Computer-Aided Design." A colloquium on "The Role of Computers in Engineering Design" was held the following day, featuring guest speakers from industry, government, and academia. The lecture series was established as a gift from Mr. and Mrs. A.H. Chatfield. Mrs. Chatfield is the daughter of **Robert Bruce Wallace,** '98. The fifth annual Robert Bruce Wallace Academic Prize, also a gift of Mrs. Chatfield in honor of her father was awarded to **Kenneth Weems,** '85.

The sixth annual Course XIII Alumni Reunion Dinner was held at the Warwick Hotel in New York on November 8, 1984. We hope to see more of you there next year! . . . The M.I.T. student section of the Society of Naval Architects and Marine Engineers kicked off its new season in September with the presentation of the SNAME banner and a Boston Harbor Cruise. A formal lecture program began later that momth with the first lecture, "Two Navies: Ours and Theirs," given by Professor **Clark Graham.**

James A. Lisnyk, S.M.'64, vice-president of the Society of Naval Architects and Marine Engineers, New York City, was killed in an automobile accident on August 1, 1984. Lisnyk's career as a naval architect began with the Bureau of Ships, Naval Ship Engineering Center in 1964; he became assistant to the technical director in 1971 and deputy director in 1973. In 1974, he joined the Maritime Administration as program manager of Advanced Ship Systems, Office of Maritime Technology. Linsnyk joined the Society in 1962, holding several positions; he wrote numerous SNAME papers and was co-recipient of the 1979 Spring Meeting Paper Award.—Patricia A. LeBlanc Gedney, Administrative Officer, M.I.T., Room 5-228A, Cambridge, MA 02139

XV

Management

If you need help on a business problem, try the Sloan Volunteer Consulting Group (SVCG). The brain-child of two second-year master's students, **Robert L. Clyatt** and **Jeffrey B. Magill,** SVCG tries to identify Sloan School master's students to serve as consultants to local industries.

"Why would any sane student with an academic schedule designed to stifle even the most modest social life volunteer time to an extracurricular project?" ask founders Clyatt and Magill rhetorically. Their answer: "Most find the opportunity to blend the outside world into class assignments a key reason for getting involved. . . . It puts the 'business' back into business school."

The second professorship in the Sloan School made possible by gifts and bequests of **Gordon Y Billard,** '24, is now held by **Stewart C. Myers,** a leading contributor to the theory of corporate finance who has been a member of the Sloan School faculty since 1966. Myers is co-author of the best-selling textbook in finance, *Principles of Corporate Finance;* he's made significant contributions to financial theory and through applied research in public utility finance, and since 1982 Myers had headed the School's Applied Economics and Finance Group.

Management of Technology Program

Edward (Ted) Finch, S.M.'84, and Jane Morse had a long phone chat in October. Ted is thoroughly enjoying his position as investment analyst for State Street Research and Management, Boston. While in Los Angeles in September he literally bumped into **Moises J. Goldman,** S.M.'84, at a CAD/CAM trade show, and they had lunch together. Ted is engaged to be married in May to Jeanne McDermott, who is a Bush Fellow at M.I.T. this year. . . . **Moises J. Goldman,** S.M.'84, expected to be in Boston at the end of October, and we're hoping he'll have time for a visit to M.I.T. He's enjoying working at Dukane Corp. as director of forward planning. Since it was a newly-created position, the company is actively developing new staff around him, and organizing new research, engineering, and marketing functions.

David C. Hite, S.M.'84, is remaining in Nashville, Tenn., for a few extra months where he continues to work with his brother's construction firm on developing software for small companies. His prototype package has been in use for several months as they continue to work out the bugs. David is also working on a possible distribution newtork for sales of the system. . . . **Gerald T. Hopkins,** S.M.'84, is still at M.I.T. taking additional courses under the support of the Army. In the meantime, he's very excited about a new "low-tech" product he's developed, and on which he has recently applied for a patent.

We're told through **Erik Chaum,** S.M.'84, that **Koichi Kodama,** S.M.'84, moved to New York City this past summer to start his new position at Mitsubishi International Corp., as project coordinator. Erik helped Koichi make the move to New York from Boston. . . . **Shang-zhi Wu,** S.M.'84, finished his dissertation in mechanical engineering last fall and began his position at the World Bank, Washington, D.C., the first of January.—Jane Morse, Program Manager, M.I.T., Room E52-125, Cambridge, MA 02139

Technology and Policy Program

Alex Demacopoulos, S.M.'84, has been named director of Information Systems at Beacon Construction, Boston. . . . **Darryl Thompson,** S.M.'84, has joined the New York firm of Stanley Morgan, prior to his entrance into the Harvard Business School in the fall of 1986.—Richard de Neufville, '60, chairman, Technology and Policy Program, M.I.T., Room 1-138, Cambridge, MA 02139

David F. Waugh, 1915-1984
Distinguished Protein Chemist

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ALLAN J. GOTTLIEB

100 Ways to Say 1985

This being the first issue of another year, we again offer a "yearly problem" in which you are to express small integers in terms of the digits of the new year (1, 9, 8, and 5) and the arithmetic operators. The problem is formally stated in the "Problems" section, and the solution to the 1984 yearly problem is in the "Solutions" section.

Problems

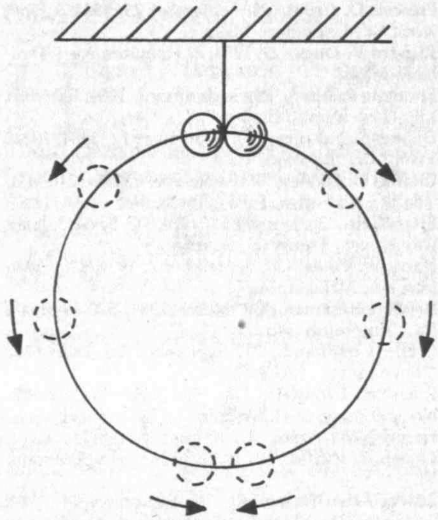
Y 1985. Form as many as possible of the integers from 1 to 100 using the digits 1, 9, 8, and 5 exactly once each and the operators +, −, × (multiplication), /(division), and exponentiation. We desire solutions containing the minimum number of operators; and, among solutions having the minimum number of operators, those using the digits in the order 1, 9, 8, and 5 are preferred. Parentheses may be used for grouping; they do not count as operators.

JAN 1. Our next problem is the last member of Emmet Duffy's collection of seven-card bridge problems. For the current challenge, South is on lead and is to take six tricks against best defense with hearts as trump:

	♠ 9 8 3 2 ♥ 10 ♦ A Q ♣ —	
♠ J ♥ 8 ♦ J 10 9 8 ♣ 5		♠ 10 ♥ 6 ♦ K 6 ♣ K J 6
	♠ A K 7 ♥ — ♦ — ♣ A Q 4 3	

JAN 2. Bruce Calder, after working on **1983 N/D 4**, sent us the following spin-off, a problem demonstrating the elegant subtlety of Newtonian mechanics:

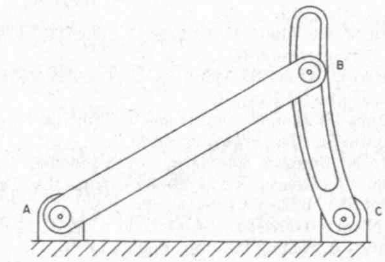
A smooth, rigid, and circular wire hoop hangs from a rigid support by an ideal, extensionless string. Two small beads slide along the hoop (like beads of a necklace) with negligible drag and friction. The beads are slid to the top of the hoop and released. How massive must each bead be to spontaneously lift the hoop?



JAN 3. Here's one John Rule dug out of the file where he keeps interesting problems encountered from various sources:

A man received a check calling for a certain amount of money in dollars and cents. When he went to cash the check, the teller made a mistake and paid him the amount which was written in cents in dollars, and vice-versa. Later, after spending $3.50, the man suddenly realized that he had twice the amount of money the checked called for. What was the amount on the check?

JAN 4. Our last regular problem is from Floyd Kosch:



SEND PROBLEMS, SOLUTIONS, AND COMMENTS TO ALLAN J. GOTTLIEB, '67, ASSOCIATE RESEARCH PROFESSOR AT THE COURANT INSTITUTE OF MATHEMATICAL SCIENCES, NEW YORK UNIVERSITY, 251 MERCER ST., NEW YORK, N.Y., 10012.

A rigid arm pivots around the fixed point A. At the end of the arm is a follower (B) which runs in a curved track. The track pivots about the fixed point C. If AB = AC = r, find the shape of the track such that its slope at C is always vertical.

Speed Department

SD 1. Here's one from Smith D. Turner (∫dt):

Bill and Joe are to be paid $10 to wrap and address a pile of packages. Joe addresses one while Bill wraps one, but Bill addresses three while Joe wraps one. How should the $10 be divided between them?

SD 2. We end with a bridge quickie from Doug Van Patter:

North:	**South:**
♠ J 6	♠ A K 7 4
♥ A Q 5	♥ K J 3
♦ A 2	♦ K J 5 4
♣ A Q 9 8 6 2	♣ K 5

You are declarer (South) in a six-no-trump contract. The opening lead of the ♦10 is taken with your ♦J. Now you wish you were in a grand slam. When you cash the ♣K, West shows out. Can you find any reasonable chance of still making your contract?

Solutions

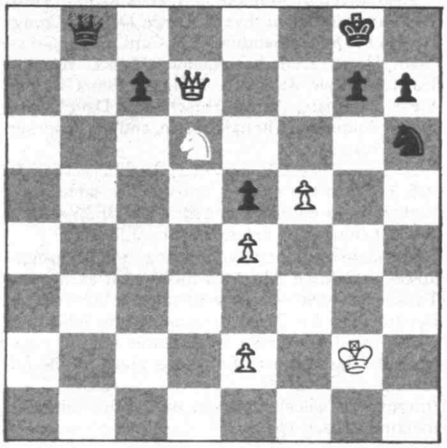
Y 1984. This is the same problem as Y 1985 (see above) with only the one digit changed.

The following solution is from Harry Zaremba; he points out that 36 numbers, shown with asterisks, use the digits in the same order as the year 1984:

*1 = 1^{984}
2 = 4/(18/9)
*3 = 1^9 + 8/4
*4 = 1 − 9 + 8 + 4
*5 = 1 × 9 − 8 + 4
*6 = 1 + 9 − 8 + 4
*7 = 19 − 8 − 4
*8 = 1 + 9 − 8/4
9 = 9 × 1^{84}
10 = 9 − 1 + 8/4
*11 = 1 × 9 + 8/4
*12 = 1 + 9 + 8/4
13 = 94 − 81
*14 = 1 + 9 + 8 − 4
*15 = 19 − 8 + 4
16 = (9 − 1) × 8/4
*17 = 19 − 8/4
*18 = 1 × 9 × 8/4
*19 = 1 + 9 × 8/4
*20 = (1 + 9) × 8/4
*21 = 19 + 8/4
*22 = 1 + 9 + 8 + 4
*23 = 19 + 8 − 4
24 = 41 − 9 − 8
25 =
26 =
27 = 9 × 4 − 8 − 1
28 = 9 × 4 − 8 × 1
29 = 48 − 19
30 =
*31 = 19 + 8 + 4
32 = 81 − 49
*33 = 1^9 + 8 × 4
34 =
35 = 9 × (4 − 1) + 8
36 = 81/9 × 4
37 = (1 + 4) × 9 − 8
*38 = 19 × 8/4
39 = 48 − 9 × 1
40 = 41 − 9 + 8
*41 = 1 × 9 + 8 × 4
*42 = 1 + 9 + 8 × 4
43 = 91 − 48
*44 = (19 − 8) × 4
45 = 81 − 9 × 4
46 =
47 = 48 − 1^9
48 = 89 − 41
49 = (1 + 4) × 8 + 9
50 = 49 + 1^8
*51 = 19 + 8 × 4
52 =
53 = (1 + 4) × 9 + 8
54 = 18 + 9 × 4
55 =
56 = 48 − 1 + 9
57 = 98 − 41
58 = 41 + 9 + 8
59 = 91 − 8 × 4
60 = (9 − 1) × 8 − 4
61 =
62 =
63 = 18 × 4 − 9
64 = (9 + 8 − 1) × 4
65 = 84 − 19
66 =
67 = 48 + 19
*68 = 1 × 9 × 8 − 4
*69 = 1 + 9 × 8 − 4
70 =
71 = 9 × 8 − 1^4
*72 = (1 + 9 + 8) × 4
73 = 9 × 8 + 1^4
74 = 84 − 9 − 1
75 = 89 − 14
*76 = 1 − 9 + 84
*77 = 1 + 9 × 8 + 4
78 =
79 = 91 − 8 − 4
80 = (1^4 + 9) × 8
*81 = 1 × $9^{(8/4)}$
*82 = 1 + $9^{(8/4)}$
83 = 84 − 1^9
84 = 98 − 14
*85 = 1^9 + 84
86 = 81 + 9 − 4
87 = 91 − 8 + 4
88 = 89 − 1^4
89 = 91 − 8/4
90 = 18 × (9 − 4)
91 = (9 + 4) × (8 − 1)
92 = 89 + 4 − 1
*93 = 1 × 9 + 84
*94 = 1 + 9 + 84
*95 = 1 + 98 − 4
96 = (9 + 4 − 1) × 8
97 = 98 − 1^4
98 = 98 × 1^4
99 = (8 + 4 − 1) × 9
100 =

Also solved by Avi Ornstein, George Aronson, Harry (Hap) Hazard, Phelps Meaker, Joe Feil, Peter Silverberg, Allan Tracht, and A. Holt.

A/S 1. Given the situation shown, White to move and win.



Bert Daniels had a little trouble with this one:
1. N-B8, K-R1 (1. . . ., P-N3 loses to 2. P-B6, N-B2, 3. Q-K8 mate; while 1. . . ., K-B1 loses to 2. Q-K7 ch and Q-K8 mate);
2. Q-Q8 ch, N-N1;
3. N-Q6 and the threat of smothered mate wins the queen.

Also solved by Matthew Fountain, Kenneth Bernstein, R. Hess, Avi Ornstein, David Evans, David Detlefs, George Aronson, Ronald Raines, Philip Dangel, and the proposer, Robert Kimble.

A/S 2. An ordinary combination padlock requires three ordered numbers to open, each between 0 and 39, inclusive. Thus there are 64,000 possible combinations. If it is known that the sum of the three numbers is 58 and the sum of the individual digits of all three numbers is 13, how many combinations are possible? If each of these possible combinations is equally likely, what is the probability that the second number is 34?

Many readers submitted computer programs that calculated all possibilities. I preferred analyses that reduced the number of possibilities to a manageable level. Matthew Fountain actually submitted both a program and an analysis. Here is the latter:

Let A equal the sum of the tens digits of the three ordered numbers and B equal the sum of the units

	Permutations	
3,2,0	6	(2)
3,1,1	3	(1)
2,2,1	3	
Total	12	(3)

( ) indicates number of permutations with 3 in second position.

	Permutations	
8,0,0	3	
7,1,0	6	
6,2,0	6	
6,1,1	3	
5,3,0	6	
5,2,1	6	
4,4,0	3	(2)
4,3,1	6	(2)
4,2,2	3	(1)
3,3,2	3	
Total	45	(5)

( ) indicates number of permutations with 4 in second position.

Number of sides	Edges each side	Total edges	Number of dihedrals	Dihedrals meeting at each apex	Number of apices
4	3	12	6	3	4
6	4	24	12	4	6
8	3	24	12	4	6
12	5	60	30	3	20
20	3	60	30	5	?

digits of the three ordered numbers. Then A + B = 13 and 10A + B = 58, with solutions A = 5 and B = 8. The table at the bottom of page A25 shows that A can be decomposed into three ordered digits, none exceeding 3, in twelve ways, and B can be decomposed into three ordered digits 45 ways. The total combinations are 12 × 45 = 540. Those with 34 as second number are 3 × 5 = 15. The probability that 34 is the second number is 15/540 = 1/36.

Also solved by Kenneth Bernstein, Richard Hess, Avi Ornstein, David Evans, David Detlefs, George Aronson, Dennis Sandow, Rita Carp, Gerry Grossman, Harry Zaremba, Richard Marks, Winslow Hartford, Yale Zussman, P. Jung, Frank Carbin, Steve Feldman, Aaron Hirschberg, Dave Mohr, Alfred Anderson, Thomas Stowe, and the proposer, John Prussing.

A/S 3. Fill in the missing entry in the table above pertaining to regular polyhedra. Can the values in the last column be determined by a formula?

The table contained two typos: a square has eight apices and three dihedrals meeting at each apex. These errors did not seem to cause much trouble. In particular, Avi Ornstein submitted the following:

The missing number is 12 apices for the icosahedron. The number of apices is given by the following:
(number of sides)(edges on each side)/(dihedrals meeting at each apex)
or
(total edges)/(dihedrals meeting at each apex)
or
2(number of dihedrals)/(dihedrals meeting at each apex).

Also solved by Matthew Fountain, Kenneth Bernstein, Richard Hess, David Evans, David Detlefs, Gerry Grossman, Harry (Hap) Hazard, Harry Zaremba, Richard Marks, Winslow Hartford, Yale Zussman, and Albert Mullin.

A/S 4. Find infinitely many positive integers n not containing the digit zero such that $n^2 - 1$ contains just two digits neither of which is zero. The digits may be repeated.

Jerry Marks sent us three patterns:

7	48	4	15
67	4488	34	1155
667	444888	334	111555
6667	44448888	3334	11115555
66667	4444488888	33334	1111155555

5	24
65	4224
665	442224
6665	44422224
66665	444422224

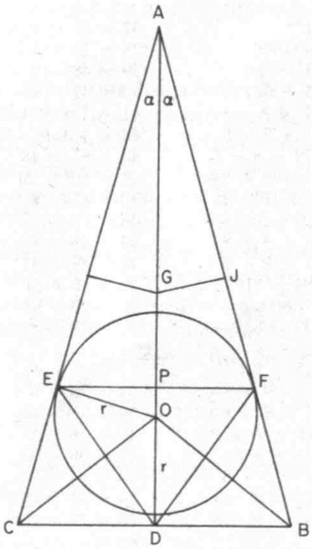
Richard Hess has a proof of one of these patterns:
$(2 \times 10^n/3 + 1/3)^2 - 1 = 4 \times 10^{2n}/9 + 4 \times 10^n/9 + 1/9 - 1$
$= 4(10^{2n} - 1)/9 + 4(10^n - 1)/9 + 4/9 + 4/9 - 8/9$
= 2n 4's + n 4's
= n 4's followed by n 8's.

Also solved by Kenneth Bernstein, David Evans, David Detlefs, Dennis Sandow, Gerry Grossman, Harry Zaremba, and the proposer, Matthew Fountain.

A/S 5. Given a triangle ABC, draw its incircle and consider triangle DEF determined by the points of tangency. Show that the area of triangle DEF is (r/d)A, where r is the radius of the incircle, d is the diameter of the circumcircle, and A is the area of triangle ABC.

We give two different solutions, the first from Kenneth Bernstein and the second from Phelps Meaker:

Bernstein begins by letting the sides of triangle ABC be a, b, and c. Define k by:
$k = \sqrt{(a + b + c)(-a + b + c)(a - b + c)(a + b - c)}$
The radius, R, of the circumcircle is abc/k. The area of triangle ABC is k/4. The radius, r, of the incircle is k/2(a + b + c). Denote the side FE of triangle FED by a′. Then a′ can be expressed in terms of r and angle A:
$(a')^2 = 2r^2(1 + (\cos A))$.
The term (cos A) can be expressed in terms of a, b, and c using the law of cosines:
$a^2 = b^2 + c^2 - 2bc \cos A$.
Combining the last two expressions:
$a' = (-a + b + c)/2 \times \sqrt{(a - b + c)(a + b - c)/bc}$,
with similar expressions for b′ and c′. The area of triangle FED is k′/4 where k′ is defined similarly to k with a′ substituted for a, etc. After much algebra, the area of triangle FED is
$k(-a + b + c)(a - b + c)(a + b - c)/16abc$
$= k^3/16abc(a + b + c)$
= (r/2R)(area ABC).



To establish his solution, Phelps Meaker lets H equal the altitude AD of triangle ABC; O is the center of the incircle; G is the center of the circumcircle; and α is one-half of the apical angle. Then, with respect to triangle AEO:
$r = EO = OD = (H - r) \sin \alpha$;
$r + r \sin \alpha = H \sin \alpha$; and
$r = H \sin \alpha/(1 + \sin \alpha)$.
With respect to triangle ABD:
$AJ = AB/2 = H/2 \cos \alpha$;

$AG = AJ/\cos\alpha = H/2\cos^2\alpha$;
$d = 2AG = H/\cos^2\alpha$.
The area of triangle ABC is
$H \times H\tan\alpha = H^2\sin\alpha/\cos\alpha$.
With respect to triangle EDF:
$EP = EO\cos\alpha$; angle $PEO = \alpha$; $OP = EO\sin\alpha$.
Then the area of triangle EDF is given by
$EP \times (OD + OP) = r\cos\alpha\,(r + r\sin\alpha)$
$= r^2\cos\alpha + r^2\sin\alpha\cos\alpha = r^2\cos\alpha\,(1 + \sin\alpha)$.
Substituting for r, the area of triangle EDF is given by
$H^2\sin^2\alpha\cos\alpha\,(1 + \sin\alpha)/(1 + \sin\alpha)^2$
$= H^2\sin^2\alpha\cos\alpha/(1 + \sin\alpha)$.
$(r/d)A = [H\sin\alpha/(1 + \sin\alpha)][\cos^2\alpha/H][H^2\sin\alpha/\cos\alpha]$
$= H^2\sin^2\alpha\cos\alpha/(1 + \sin\alpha)$.

Also solved by Matthew Fountain, Richard Hess, David Evans, Robert Hollenbach, Henry Lieberman, Mary Linderman, Howard Stern, and the proposer, Harry Zaremba.

Better Late Than Never

1983 JUL 5. Matthew Fountain sent us the following:
Donald Savage's comments on **1983 JUL 5** stimulated me to further investigation. I found (a) there are $29(2)^n$ n-digit numbers whose squares are suitable with respect to their last n digits and (b) there are $29(2)^n(0.2)^r$ n-digit numbers whose squares are suitable with respect to their last n + r digits; (a) is exact when $n>3$; (b) is an excellent approximation when n is large and r small. Both (a) and (b) are consistent with the notion that the middle digits of squares are representative of random numbers, except that (a) is more than chance. I wrote a Pascal program that generated all the (a) numbers up to and including those of 20 digits and printed out those that came closest to having entirely suitable squares. My IBM took about 2.5 days to cover the range of 15 through 20 digits. I found that the results differed from (b) because of the pecularity of two sequences of digits. For example, (b) expects there to be 3.1 numbers of 20 digits or less with squares having their last 30 digits suitable. Actually there are 22. But 15 differ from 83,333,333,333,333,333,332 only in the first six or less digits, and four differ from 21,666,666,666,666,666,662 in the first five or less digits. Only 78,537,356,970,849,674,736 appears to resemble a random number. My conclusion is that (b) is probably a good estimate of the odds that there exists a large n-digit number with an (n + r)-digit square, all of whose digits are suitable. The pecularity of the two sequences should not affect (b) when r = n or r = (n − 1). The odds, of course, seem very small. It is interesting that Los Alamos in its early days took sequences of digits from the middles of consecutive squares as random numbers, a suggestion of von Neumann. Some cyclic patterns were observed, the worst being too many consecutive zeroes.

1984 APR 1. Harry (Hap) Hazard points out that spades can be led or steel but not lead.

APR 2. Richard Halloran has responded.

M/J 5. Dayton Datlowe has responded.

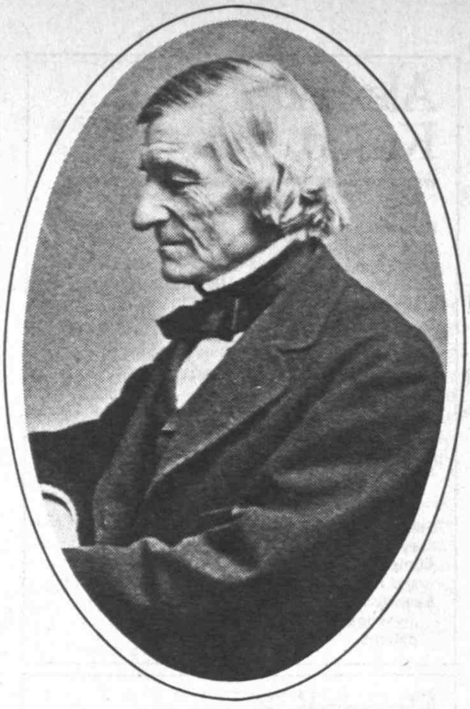
JUL 2. Ivor Morgan and Mary Lindenberg have responded.

A/S SD2. Arthur Carp, Ronald Martin, and Gordon Thomas report that pan's dimensions are 7 × 5 × 1.5 inches.

Proposers' Solutions to Speed Problems

SD 1. The editor needs to assume that the speed ratio between Joe and Bill is constant for wrapping and addressing. In that case, the ratio is $\sqrt{3}$ and Joe should receive
$\$10/(1 + \sqrt{3})$.

SD 2. Lead low toward the ♠J, and hope West has the ♠Q. (My partner found this line of play, but most declarers went down.)



Massachusetts Institute of Technology

Report of the President

For the Academic Year 1983–1984

The idea of MIT began in the mind of one man — William Barton Rogers — and took root in a fertile setting: in nineteenth-century America, in Boston. It was an idea that captured the imagination and intellectual energy of those citizens who saw the need for a new kind of education which would emphasize, in Rogers's words, ". . . the value of science in its great modern applications to the practical arts of life, to human comfort, and health, and to social wealth and power." The founding idea was accompanied by an impulse, a spirit, which was just as revolutionary as the idea itself: the spirit of inventing the future. Rogers was not bound by the traditional ways of organizing and seeking knowledge; his entrepreneurial spirit and willingness to take risks in pursuit of an exciting idea **are** the MIT tradition.

As MIT has grown, it has embraced and invented a host of intellectual domains. Our departments and academic programs reflect in their names and in their activities the remarkable ability of the faculty to anticipate and shape the future. Scores of interdepartmental research laboratories and centers constitute perhaps an even more sensitive barometer of the ways in which MIT transcends the boundaries of tradition in both organization and style.

Today, our fields of study and scholarship include management, urban planning, humanities and the social sciences, as well as the natural sciences, architecture, and engineering. MIT has become more than an institute of technology in the nineteenth-century sense of that phrase. To use the words of James R. Killian, Jr., first spoken in 1949, MIT is "a university polarized around science, engineering, and the arts." And yet the founding idea of MIT continues and is central to our future, for we are now and must remain the strongest science-based research university in the world. Our historic commitment to scientific and quantitative methods remains at the core of our approach to learning; it permeates the whole spectrum of our degree programs, and is a touchstone of common interest and purpose for all who study, teach, and work here.

Given this foundation, MIT's current mission can be stated succinctly: to provide the highest quality programs of education and research in each of those areas of study and investigation in which we have developed strength and competence, and to do so with a strong commitment to public service and to a diversity of backgrounds, interests, and points of view among the faculty, students, and staff.

PHOTOGRAPH OF WILLIAM BARTON ROGERS: M.I.T. MUSEUM

How does this mission translate into programs and plans for MIT today and in the decades to come? The insistence on the highest standards for all that we do — in education, in research, and in the services necessary to support this academic endeavor — is taken for granted. The faculty, students, and staff of MIT set extraordinary standards for themselves — and surpass them more often than not. Combined with, and in many ways derived from, this insistence on the best has been the variety of interests and perspectives among the people of MIT. Indeed, this diversity has long been a source of great strength. We have welcomed students from all economic circumstances, many of whom have been the first generation of their families to pursue higher education. And for over a century, we have enjoyed and benefited from a cosmopolitan, international student body and faculty. Indeed, few U.S. colleges or universities are better known overseas.

Within the last two decades, we have seriously begun to broaden the gender and ethnic diversity of our population. Our efforts on this score have been only partially successful. While we have made some progress, to be sure, the representation of women and most minority groups among the undergraduates is at about half of the number that would be expected on the basis of their distribution in the population of this country. In the graduate school, their representation is even lower, and in the faculty it is lower still. This situation will not change quickly, but deserves our continued and heightened attention if we are to succeed in making MIT more attractive and hospitable to minorities and women. My own sense is that we might make progress faster in today's environment if we were to focus more intensively on specific, short-term goals for each year, try **very** hard to realize them, and then move on to set new ones. Such an approach may help give an immediacy and a greater sense of priority to these important objectives.

Diversity of interests and points of view extends to our goals for the educational program as well. All undergraduates at MIT are expected to obtain a solid base in the natural sciences and in quantitative methods of learning, on the one hand, and in the social sciences, humanities, and arts, on the other. In practice, this symmetry is less than complete. Our undergraduates are indeed exceptional young men and women, many of whom have a wide range of interests — interests which could equally well be satisfied and developed at a general university. If judged by their choice of major, however, the focus of their interests has narrowed in recent years to a handful of engineering and science departments. In fact, one department — Electrical Engineering and Computer Science — now enrolls more than a third of all undergraduate majors.

This profusion of academic majors in a few departments has several unfortunate consequences. First, it places painful pressures on the faculty in those departments simply to keep up with the extraordinary demand for teaching and advising, making it much more difficult to spend time on curriculum development and scholarly renewal. Such pressures, if not checked, could well lead to a decline in the quality of the educational programs of those very departments now so much in demand by the students. Concentration in a few departments also means a dispiriting decline in the number of students majoring in other departments. In the face of a student culture that devalues certain areas of study, it is becoming harder for MIT undergraduates to maintain a serious academic interest in fields other than science and engineering. We run the risk of attracting principally those students whose interests are much narrower than the resources we have to offer. The quality of our education will erode and the intellectual climate both inside and outside the classroom will suffer if these trends are allowed to continue.

All undergraduates at M.I.T. are expected to obtain a solid base in the natural sciences and in quantitative methods of learning.

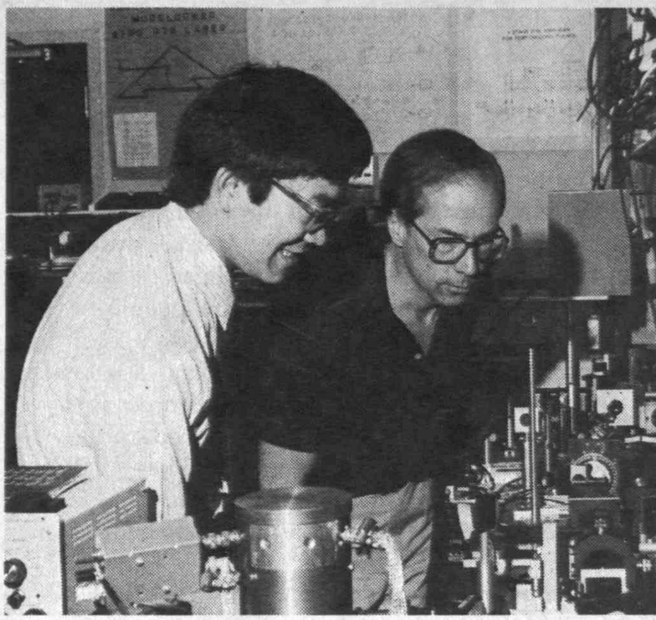
MARK WILSON

The quality of an institution depends on the standards and the vision it sets for itself. It depends, also, on the ability to make the most out of its resources and its potential. As a science-based university, even as an institute of technology, we must come to terms with the challenge and the responsibility to educate our undergraduates liberally. This is a challenge because many in

our society have come to equate college education with professional preparation. Certainly we have an interest, even a stake, in preparing students for contributions to society. And many, indeed most, MIT undergraduates express a passionate interest in moving swiftly toward their professional objectives. If we become the champions of early preprofessional training at the expense of a broader academic vision, however, our graduates will become increasingly specialized in their skills and limited in their fields of vision. At the undergraduate level, it is our responsibility to help students understand the many ways of seeing, knowing, and understanding the world. The liberating quality of education develops precisely through our ability to explore the natural and social orders from a variety of perspectives and to integrate, easily and unselfconsciously, knowledge gained through our feelings and our intellects.

MIT's brand of liberal education must include those ways of perceiving, understanding, and communicating that at any time and in any place allow access to the world in which we live. In contemporary post-industrial society, a liberal education must encompass the arts, engineering and technology, humanities, science and mathematics, and social science. It is up to us to organize and to present that array in judicious balance. The educated will find imaginative ways of reassembling it as they come to terms with the worlds within and around them. Some will focus on those studies which seem most relevant to their professional interests. Others, including some who are more conscious of the likelihood of future changes in interest and career, will choose a broader path through the curriculum. But all of our students will spend their professional lives working under circumstances in which the linkages among science, technology, and human affairs bear directly on their work and in which the ethical and moral consequences of their work will be more easily questioned and more frequently called upon for discussion and defense. The education we provide must enable our alumni to meet and engage their professional and personal worlds as fully and as responsibly as possible.

The challenge of providing a liberal and liberating education for the extraordinary young people who come here as undergraduates is in no way inconsistent with our historic mission or our present strengths. The intellectual diversity and innovative spirit of the Institute — present in Rogers's founding proposition that education must meet the spirit and the needs of the times — is nowhere more evident than in the activities of the faculty. These men and women have the ideas, inspiration, and energy to reshape whole fields of intellectual inquiry and to invent new ways of organizing and applying knowledge for practical purposes. A few examples drawn from the events of the past year will illustrate the way in which the insights, instincts, and entrepre-



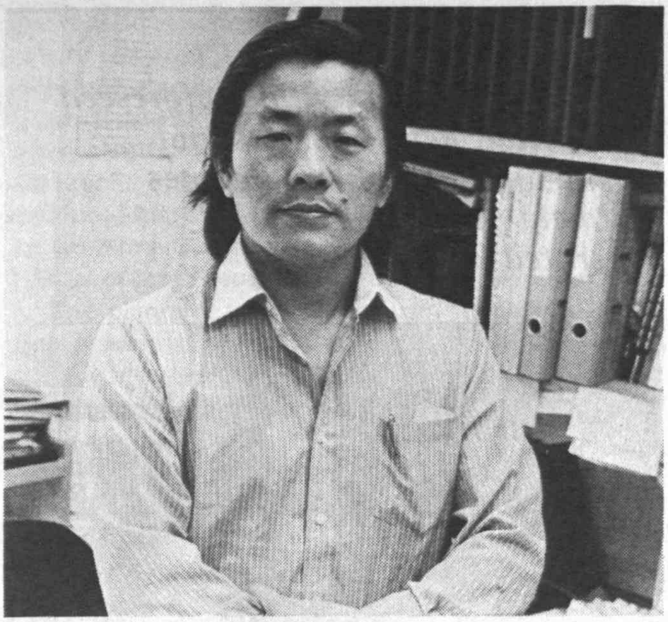
RUSS CLARK

Professor Erich I. Ippen (right)

Working with his graduate students in the Research Laboratory of Electronics, Professor Ippen made scientific history by generating and measuring the quickest flashes of light ever produced.

M.I.T.'s brand of liberal education must include those ways of perceiving, understanding, and communicating that at any time and in any place allow access to the world in which we live.

RICH REIHL



SIDHU BANERJEE

Professor Susumu Tonegawa

Professors Susumu Tonegawa and Herman N. Eisen have described the complete structure of the receptor on T cells that is believed to account for the recognition of antigens by these cells.

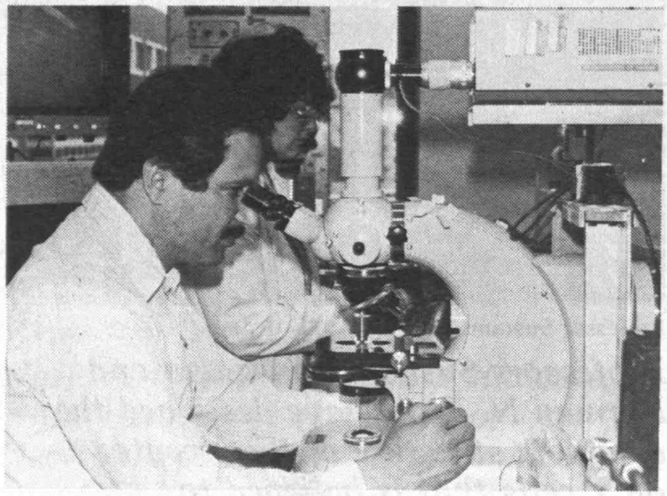
neurial spirit of the faculty continually shape the course of MIT's development.

- Professor Erich P. Ippen of the Department of Electrical Engineering and Computer Science, working with his graduate students in the Research Laboratory of Electronics, made scientific history by generating and measuring the quickest flashes of light ever produced. These laser-generated pulses have a duration of about sixteen femtoseconds (16×10^{-15} seconds). The techniques for generating and observing these very short pulses were created during the course of a research program aimed at developing high-speed, optical information processing systems — systems which may one day permit computers to operate at speeds higher than those imposed by the limits of electronic devices. These short light pulses are also useful in studying the behavior of molecules and crystalline materials because they can "freeze" events which occur at atomic and molecular time scales, just as the strobe lamp, invented more than fifty years ago by Institute Professor Emeritus Harold E. Edgerton, is able to freeze events which occur on the time scales of the macroscopic world.
- Project Athena, which was described in this report a year ago, has taken the first steps toward operational reality. This large-scale educational experiment is aimed at developing and appraising ways in which convenient access to networked computer work stations can influence the structure and content as well as the teaching and learning associated with the educational programs of the Institute. The Project is well under way, with computers and cables being installed in academic buildings and libraries throughout the Institute. Last spring, in the first two rounds of grants for curriculum development, just over $1 million was awarded to faculty members for 49 projects, and a score of experiments in the classroom and laboratory are scheduled to begin during the fall term. With such a massive experiment in teaching and learning taking place in every corner of the Institute, we need to understand and to assess the changes which are taking place not only in individual subjects but in the general academic culture of MIT. Toward that end, I am designating $250,000 — the major portion of this past year's Sustaining Fellows Fund — for the support of faculty initiatives to understand the educational impact of Athena in specific subject areas as well as on learning styles and on the ways we communicate with each other more generally.
- Within the past year, the Sloan School of Management has embarked on a number of programs aimed at encouraging broader, more innovative uses of new computer and communications technologies in its educational and research activities. The management science faculty within the School, for example, has proposed a redesign of a major portion of the core curriculum in the master's program around an integrating theme of decision support systems, which would make heavy use of personal computers and related capabilities. These and other changes being proposed by the master's program committee are seen as necessary responses to changes in discipline-based knowledge and to technological innovations that may reshape some dimensions of management practice. Such initiatives offer exciting opportunities to strengthen the currency and impact of the School's educational and research programs, and are, once again, examples of the way in which MIT faculty look to the future to inform the present.
- Work in the Center for Cancer Research and the Department of Biology has led this year to several significant advances in efforts to understand, at the molecular level, the mechanisms which cause cancer and the ways in which the body's immune system eliminates cancerous cells. Professor Robert A. Weinberg and his colleagues have recently identified the precise molecular difference between the gene which causes human bladder cancer and the corresponding normal growth-control gene. The difference between the normal gene and the oncogene is extraordinarily small; just one nucleotide or molecular unit of the DNA (which is composed of about 5,000 units) is out of sequence. This understanding of the genetic basis for a cancer cell may lead to insights into the ways

in which carcinogens operate. Also this year, Professors Susumu Tonegawa and Herman N. Eisen and their associates have described the complete structure of the receptor on T cells that is believed to account for the recognition of antigens by these cells. These T cells seek out and destroy cells foreign to the body, including cancer cells. This new knowledge sheds light on an important piece of the immune system puzzle; it may lead to enhancement of T cells' ability to attack cancer cells and to the possibility of suspending T cell activity so that transplants are not rejected.

- The Whitehead Institute for Biomedical Research, a separate research organization affiliated with MIT, has occupied its new building in Kendall Square. Established in 1982 with funds provided by Edwin C. Whitehead, this nonprofit research institution is directed by Nobel laureate David Baltimore, American Cancer Society Professor in our Department of Biology. Several members of the faculty, including Professor Weinberg, who have appointments in the Whitehead Institute, have moved into the new facilities. Members of the Whitehead Institute teach as professors at MIT, and some of our graduate students do their research at the Whitehead Institute. This novel arrangement greatly enhances the strength of biological research and education at MIT.
- Last fall, the School of Architecture and Planning announced the establishment of a Center for Real Estate Development, made possible by the generous support and intensive personal involvement of Charles H. Spaulding. By focusing on specific management and policy issues attendant to real estate development, the Center contributes to the larger issue of shaping the physical environment that we will bequeath to the future. Interest in the Center, and in the associated master's program which begins this fall, has greatly exceeded our expectations. Also during the year, the new interdisciplinary Media Laboratory was formally established within the School. Under the direction of Professor Nicholas Negroponte, the Laboratory's activities address the invention and creative use of new media and will be housed in the Arts and Media Technology facility, now nearing completion. This year saw the beginning of an intensive and collaborative period of program development among the various groups that make up the Laboratory.
- Another example of the way in which research centers bring together faculty and foster synergism among different intellectual areas is found in the Center for Cognitive Science. The Center draws together faculty from Psychology and from Linguistics and Philosophy to work on problems of perception, cognition, and language. This year saw intensive development of the Center's Multi-User Laboratory, which provides the cognitive science community at MIT with computational facilities for data analysis, simulation, text processing, information management, and on-line control of experiments — another illustration of how advances in information processing technologies are helping to support and advance fields throughout the Institute.

Academic planning at M.I.T. is strongly influenced by unforeseen intellectual developments and by the unpredictable outcomes and new opportunities generated by research.



DAVID R. LAMPE

These are but a few of the notable achievements and initiatives undertaken by individual faculty members and by groups of faculty working together to define and contribute to the world of knowledge and practice.

At the institutional level, the department heads and deans, along with other members of the administration, have invested much time and effort over the past two years in the development of five-year plans for every area at MIT. The Provost has convened and chaired an Institute Planning Group to oversee these efforts. The overall objective of this planning activity is to put in place a process to review, renew, and extend each year a set of long-range strategic plans for the Institute. This process will encourage the anticipation of critical decisions about alternatives and the forecasting of resource needs. The planning is intended to serve as a normative framework, subject to review and change, and **not** as a set of rigid constraints.

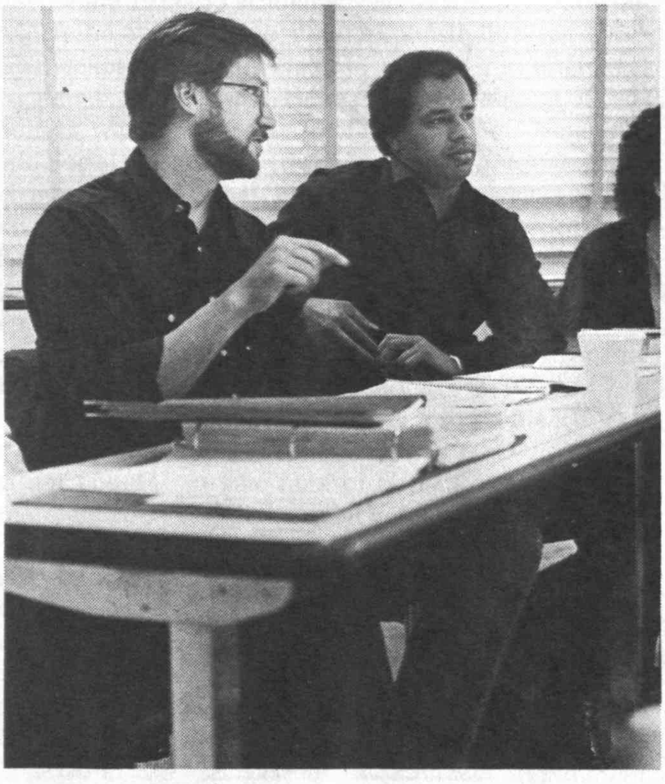
Academic planning at MIT — indeed at any institution in which the future is strongly influenced by unforeseen intellectual developments and by the unpredictable outcomes and new opportunities generated by research — is, of necessity, a delicate business. It must originate in the departments and laboratories, it must be guided with a light hand, and it must be employed in a manner which recognizes the inevitability of surprises. At the same time, planning encourages a

self-conscious approach to choices between alternative uses of resources and paths of development, and it enables assessment of both resource limitations and future resource needs. This is especially important at a time when constraints on money and space are major considerations affecting the future of the Institute. I am convinced that this planning activity, which has required the investment of much energy by people throughout MIT, is of great benefit to us, now and in future years.

The planning activity has given immediacy and a greater sense of priority to our future resource needs — needs which have long been present but which have been less explicitly defined.

Jerome B. Wiesner, the thirteenth president of MIT, has said that when he was a young member of the faculty, the most important quality of the Institute for him was the fact that every assistant professor could do exactly what he or she wished to do. All it took was a solid idea and the initiative and persuasiveness to convince one or two others. The necessary resources of money, space, and equipment would somehow be found. This ready access to support for compelling ideas is, regrettably, no longer universally the case, largely because of constraints on funds, both internal and external.

At the student level, there is no definitive evidence that the cost of our educational programs has caused any decline in the quality of those who apply.



BRADFORD F. HERZOG

How have our circumstances changed? The modern development of MIT was paced by the postwar involvement of the federal government in the support of graduate education and research. In the period up to 1968, the rapid growth in that support saw the MIT faculty more than double in size, the graduate students match the undergraduates in number, and a great expansion in the size of the physical plant as well as the budget.

For several years following 1968, there was a decline in real terms, and then a levelling off, in federal support of basic research at colleges and universities. For the past eight years, there has been growth again, but at MIT this growth has not been steady.

At the same time, the costs of education and research have steadily increased, fueled by a decade of high inflation and the introduction of new techniques and instruments which are both more effective and substantially more expensive. These increases are now reflected in the Institute's tuition, which is among the highest in the nation, and in the cost of its research programs. While the latter is harder to quantify in terms which permit ready comparisons with other universities, there is a pervasive sense that research at MIT costs a fifth or so more than at most of the research universities with which we compete for research support, for the strongest students, and for the most talented faculty.

While these cost differences do not presently seem to affect either the quality of work done here or the underlying strength of the faculty, it is clear that they do make it more difficult for faculty to obtain research funding and to develop and sustain evolving research programs. The principal consequence of these cost differentials is to raise the "intellectual overhead" which faculty must spend in seeking and sustaining research support. We are very much concerned about the corrosive long-term effects of this problem.

At the student level, there is no definitive evidence that the cost of our educational programs has caused any decline in the quality of those who apply. Demand, as measured by the number of students who apply and who accept our offer of admission, remains strong. In fact, at the undergraduate level and in many areas of graduate study, these measures have increased. But we recognize the crucial importance of financial aid for both undergraduate and graduate students in sustaining a student body of the highest quality, and here, too, we are concerned that increasing costs may place serious constraints on our ability to enroll the most promising students regardless of their economic circumstances.

We have, during the past three years, undertaken a comprehensive review of operating budgets which has enabled us to reduce ongoing operating expenses by about $11 million per year (in 1984 dollars). Nearly all of these reductions were achieved in support areas. While academic budgets have also been reduced in most departments, these recaptured funds have been allocated to those departments which have experienced significant increases in enrollment; consequently, the net change

CALVIN CAMPBELL

We cannot help but conclude that the needs of M.I.T. are so great because M.I.T. itself is so much needed!

in aggregate academic budgets over these three years is very small.

The budget reductions have had a beneficial effect both on the operating budget and on the research indirect cost rate. This past year, we were able to achieve a small surplus ($0.8 million) in the operating budget — a result due in large measure to the remarkable efforts to contain costs which were made by people throughout the Institute. They deserve thanks for a job well done.

The future financial and academic integrity of MIT, however, cannot be secured by a steady diet of budget reductions. In fact, both the quality of our programs and the spirit of this community would wane if we were to rely only on cost containment efforts in order to meet our funding needs.

Even when annual gifts reach close to $50 million, as they did this past year (nearly matching the prior year's record level), they cannot address the chronic and fundamental need for a larger endowment. Endowment plays a special, critically important role in the operation of a university. It underwrites the basic academic activities and provides, as well, the venture funds or seed money required to launch new activities and to explore promising new areas of inquiry. It supports the educational activities of students through scholarships and fellowships. It moderates cost pressures on tuition charges and on the price of research. By providing a stable base of support for faculty, it mitigates the relentless pressure of searching for outside research funding.

During these past four years, I have become completely convinced that not only is the Institute's endowment presently too small by a substantial margin but that, as a corollary, this capital base must be greatly expanded if we are to secure MIT's future as the premier science-based university in the world.

This is, of course, not the first time a president has seen the needs of the Institute in such terms. Almost a century ago, President Francis Amasa Walker wrote in his annual report:

"In this effort to make the Massachusetts Institute of Technology second to none in the world, the Corporation have succeeded — thanks, largely, to the zeal, learning, and sound judgment of a devoted and self-sacrificing body of professors and instructors. . . . But I think no one can know much of this school without having a strong conviction that the full time has now come, when it requires for its greatest usefulness, for the maintenance of its high character among the scientific institutions of the world, and for its security against disaster and business depression, large, very large, additions to its permanent investments. . . . The needs of the Institute are so great, because the Institute itself is so much needed. . . ."

How much more true are those words today. When we look at our achievements and the role of MIT in the world, when we look at our aspirations and our long-range plans, we cannot help but conclude that the needs of MIT **are** so great because MIT itself **is** so much needed!

Paul E. Gray
October 1984

In Special Recognition

Every year there are occasions which remind us of the uniqueness of individuals who collectively mold the character of the Institute. This past year several key leadership roles at the Institute have changed, and those transitions were occasion for special recognition.

In the fall of 1983 Stuart H. Cowen asked, for health-related reasons, to be relieved of his responsibilities as Vice President for Financial Operations. During his 10 years as Vice President, Stuart Cowen's exceptional talents as financial analyst and manager, skillful negotiator, and academic colleague have combined to make the Institute a leader in the development of policy governing the relations between research universities and the federal government, and his standing among university financial officers is without peer. Under his stewardship, the Institute has maintained a steady financial course during increasingly difficult times. His determination, his courageous spirit, and his unyielding will are an example to us all.

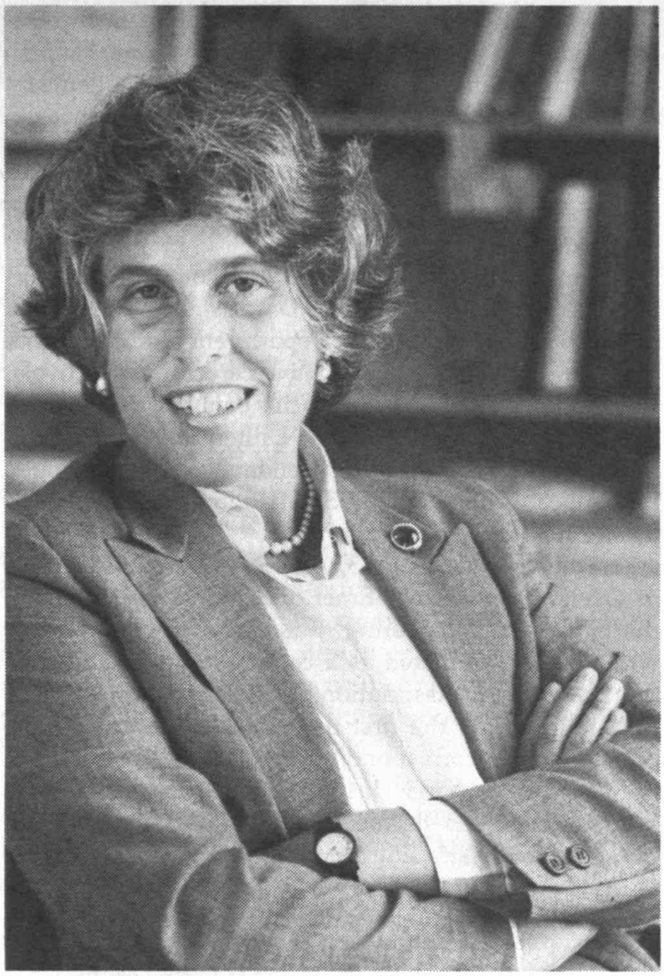
After nearly 11 years of service, Harold J. Hanham, Dean of the School of Humanities and Social Science, announced that he would be leaving the deanship at the end of August 1984. During his term in office Dean Hanham nurtured scholarship and educational excellence in the School of Humanities and Social Science and was also responsible for guiding through a major revision in the Humanities, Arts, and Social Sciences Requirement. His term of office will also be noted as a period when the graduate programs in economics, linguistics, philosophy, and political science consolidated their position among the best in the country. Dean Hanham plans to devote the 1984–85 academic year to writing, following which he will assume new responsibilities as Vice-Chancellor of the University of Lancaster in England.

Ann F. Friedlaender, Head of the Department of Economics, was appointed Dean of the School of Humanities and Social Science, effective September 1, 1984. A gifted economist and teacher, Professor Friedlaender is widely known for her work in the field of public finance, with a specialization in transportation studies. She came to MIT in 1972 as a visiting professor, and in 1974 was appointed professor in the Department of Economics and the Department of Civil Engineering. She became Head of the Department of Economics in 1983.

The special character of MIT is also seen each year in the achievements and honors of its faculty. While it is not possible to take note of every such distinction, there are some highlights which deserve mention.

In the spring the National Academy of Engineering elected as a member Joseph L. Smith, Jr., Department of Mechanical Engineering. This election brings to 72 the number of MIT faculty and staff who are members of the NAE. Ralph Landau, Life Member of the Corporation, was elected to another four-year term as Vice President of the Academy.

Also in the spring Peter A. Diamond, Department of Economics, was elected to the National Academy of Sciences, and Vera Kistiakowsky, Department of Physics, was elected a Fellow of the American Association for the Advancement of Science.



BRADFORD F. HERZOG

Professor Ann F. Friedlaender

A gifted economist and teacher, Professor Friedlaender is widely known for her work in the field of public finance, with a specialization in transportation studies.

Mildred S. Dresselhaus, Abby Rockefeller Mauze Professor of Electrical Engineering and Physics, was elected President of the American Physical Society, serving as President-Elect in 1983 and President in 1984.

Eight members of the MIT faculty were among the 73 Americans elected to the American Academy of Arts and Sciences this year. New MIT members are: George B. Benedek, Alfred H. Caspary Professor of Physics and Biological Physics; B. Clark Burchfiel, Schlumberger Professor of Geology in the Department of Earth, Atmospheric, and Planetary Sciences; Gerald R. Fink, Professor of Genetics in the Department of Biology and at the Whitehead Institute for Biomedical Research; William

D. Kingery, Kyocera Professor of Ceramics in the Department of Materials Science and Engineering; Hamish N. Munro, Adjunct Professor of Physiological Chemistry in the Department of Nutrition and Food Science; K. Barry Sharpless, Professor of Chemistry; Lester C. Thurow, Gordon Y Billard Professor of Economics and Management; and Susumu Tonegawa, Professor of Biology.

Former Presidential Science Advisor and MIT Corporation Member, Edward E. David, Jr., and Professor Kenneth M. Hoffman of the Department of Mathematics served as Chairman and Executive Director, respectively, of the National Research Council's commission to assess the state of mathematics in the United States. The commission's findings and recommendations were contained in a report, "Renewing U.S. Mathematics," published by the National Academy Press.

In the summer of 1983, Alfred A. H. Keil, Professor of Ocean Engineering, Emeritus, and former Dean of the School of Engineering, was accorded a rare honor when he was inducted as a corresponding member of the 127-year-old Association of German Engineers. The occasion marked the first time the association has inducted foreign corresponding members since 1869.

Jerrold R. Zacharias, Institute Professor Emeritus, was awarded the 1983–84 medal of the International Commission for Physics Education.

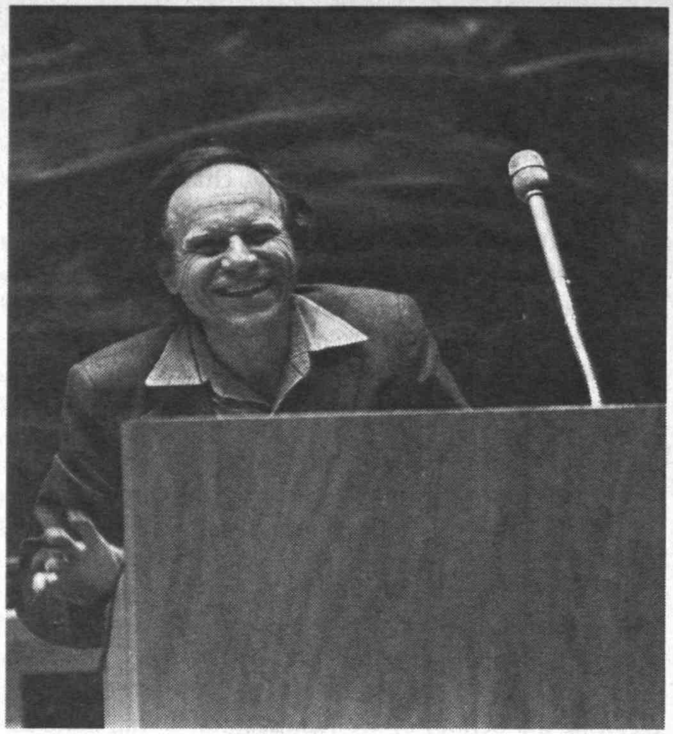
In the late spring Samuel A. Goldblith, Vice President for Resource Development and Professor in the Department of Nutrition and Food Science, was awarded the Second Class of the Order of the Sacred Treasure by the Emperor of Japan. Professor Goldblith was selected to receive this award for his promotion of friendly relations and mutual understanding between the United States and Japan.

John S. Waugh, Arthur Amos Noyes Professor of Chemistry, was named a co-recipient (along with Professor Herbert S. Gutowsky of the University of Illinois at Urbana and Professor Harden M. McConnell of Stanford University) of the 1984 Wolf Foundation Prize in Chemistry and received the prize from Israeli President Chaim Herzog at a special meeting of the Israeli Knesset. This year's prize was given for the independent research pursued by these scientists in magnetic resonance spectroscopy as applied to chemistry.

In the spring Robert A. Weinberg, Department of Biology, received the seventh annual Bristol-Myers Award for Distinguished Achievement in Cancer Research.

In the winter Richard B. Melrose of the Department of Mathematics received the Bocher Prize of the American Mathematical Society "for his solution of several outstanding problems in diffraction theory and scattering theory and for developing the analytical tools needed for their resolution."

Two MIT faculty members were the recipients of MacArthur Prize Fellows awards given by the John D. and Catherine MacArthur Foundation to recognize and give certain talented individuals the financial freedom to pursue their interests. The recipients were Professor Heather N. Lechtman, whose research in anthropology and archaeology combines the physical sciences and the humanities, and Professor Michael J. Piore, an economist known particularly for his concept of the "dual labor market" in industrial societies.



UNDERGRADUATE ACADEMIC SUPPORT OFFICE

Professor Philip Morrison

Scientific knowledge and understanding is not purely a cerebral affair; it is soaked with emotion, excitement, and nervous tension, as everyone knows who has ever heard Professor Philip Morrison talk.

In April, Institute Professor Philip Morrison was selected by faculty colleagues to be the 1984–85 recipient of the James R. Killian, Jr., Faculty Achievement Award. The Award recognizes extraordinary professional accomplishments and service to the Institute. The committee's citation reads, in part, "No one has better demonstrated, or rather embodied, what it means to the human soul to perceive or recognize a new scientific discovery or a new theoretical insight. Scientific knowledge and understanding is not a purely cerebral affair; it is soaked with emotion, excitement, and nervous tension, as everyone knows who has ever heard Philip Morrison talk."

In May, Associate Professors Joshua Cohen of the Department of Linguistics and Philosophy and Jae S. Lim of the Department of Electrical Engineering and

Computer Science were co-recipients of the Harold E. Edgerton Faculty Achievement Award. The Award recognizes young faculty members for outstanding achievements in research, scholarship, and teaching.

Several changes in senior posts in the academic administration were announced this past year. In December 1983, Steven R. Lerman, Department of Civil Engineering, was appointed director of Project Athena. Other changes in the academic administration during the year included H. Kent Bowen, Director of the Manufacturing Systems Program; Arthur P. Mattuck, Head of the Department of Mathematics; Gordon H. Pettengill, Director of the Center for Space Research; Charles H. Spaulding, Director of the Center for Real Estate Development; and J. Kim Vandiver, Head of the Experimental Study Group.

Several changes in the Institute's central administration also were announced during the year. These include the selection of James J. Culliton as Vice President for Financial Operations, succeeding Stuart H. Cowen. Mr. Culliton assumed his new responsibilities June 1, 1984. Mr. Culliton had been Assistant to the Vice President in the Office of the President and Director of Personnel since 1978. Joan F. Rice, Manager of Personnel Services and Development, succeeded Mr. Culliton as Director of Personnel on June 1. D. Hugh Darden was appointed Assistant Treasurer for Planned Gifts and Legal Affairs.

At Lincoln Laboratory, John A. McCook became Assistant Director on July 1, 1984, upon the retirement of Henry W. Fitzpatrick, who served the Laboratory since its inception over 30 years ago. In May 1984, Peter H. Richardson, Director of Admissions, announced his decision to retire from the post in September. A search has been launched to select his successor.

The Institute was saddened this year by the deaths of several longtime friends and colleagues. We miss their presence among us and are grateful for their contributions to this community.

Gordon Y Billard, a graduate of MIT who became a major supporter of the Sloan School of Management, died in September 1983 at the age of 83. During his career he served as a financial consultant, engineer, economist, investment banker, and corporate director of many companies.

In February 1984 Evers Burtner, Professor of Naval Architecture and Marine Engineering, died at the age of 90. Upon his retirement from MIT, he was one of the last two faculty members to have begun teaching at "Boston Tech" before MIT moved to Cambridge.

Samuel C. Collins of the Department of Mechanical Engineering, internationally known as the father of practical helium liquefiers and founder of the MIT Cryogenic Engineering Laboratory, died in June 1984 at the age of 85. Professor Collins and his colleagues built what became known as the Collins Helium Cryostat — a device which revolutionized cryogenics and made the practice of that science possible in many universities.

Nathaniel H. Frank, former Head of the Department of Physics, died at the age of 80 in February 1984. Though his professional fields of specialization were theoretical physics and metallic conduction, Nathaniel Frank was particularly interested in physics education and worked to restructure physics curricula in the nation's high schools.

Mason Haire, formerly a Professor at the Sloan School of Management and a pioneer in the application of psychology to the problems of management, died in June 1984 at the age of 68. Known for his innovative methods for looking at the way people relate to organizations and organizations to the world, he made important contributions to a vital area in the Sloan School.

In December 1983 Robert S. Harris died at the age of 79. Known for his research on the roles of vitamins, minerals, fats, and proteins in the metabolic process, he served as a member of the faculty in the Department of Nutrition and Food Science for 41 years.

Kevin A. Lynch, internationally known for developing the field of urban design and for his pioneering work in establishing the basic theories of how cities are perceived and organized by those who live in them, died in April 1984 at the age of 66. His career spanned 35 years of research, teaching, and practice, largely focused at MIT where he was Professor of City Planning in the Department of Urban Studies and Planning, which he joined in 1949.

Retired Chairman of the Board of T. Rowe Price Associates, Inc., and a member of the MIT Corporation, E. Kirkbride Miller died at the age of 66 in June 1984. A distinguished leader in investment banking, he was also a devoted alumnus who participated in the activities of both the Alumni Association and the Corporation.

In October 1983 Robert B. Newman died at age 73. He was an internationally known acoustical consultant and lecturer who served as a member of the faculty in the Department of Architecture for 27 years and was a co-founder of Bolt Beranek and Newman, Inc., of Cambridge.

Stephen M. Paneitz, Assistant Professor in the Department of Mathematics, died at the age of 28 in September 1983. After receiving his Ph.D. in June 1980 from MIT, he was a Miller Fellow at Berkeley, returning to MIT in September 1982 as a member of the faculty.

Ithiel de Sola Pool, Ruth and Arthur Sloan Professor of Political Science and an authority on the social impacts of modern communications systems, died in March 1984 at the age of 66. A pioneer in the field of communications research, he combined a grounding in classical political theory and humanistic historical perspective with rigorous quantitative social science methods. He joined the MIT faculty in 1953 and was instrumental in founding the Political Science Department, turning it into a major department with an international reputation.

In February 1984 James F. Thomson, Professor Emeritus of the Department of Linguistics and Philosophy, died at the age of 62. A specialist in mathematical

logic and computation theory, James Thomson was instrumental in establishing the philosophy program's strength in analytic philosophy.

B. Alden Thresher, former Director of Admissions at MIT and long considered the "dean" of admissions officers in the United States, died in January 1984 at the age of 87. He held the position of Director of Admissions from 1936 to 1961, and made outstanding contributions to the theory and practice of his profession.

In February 1984 Harold C. Weber, Professor Emeritus of the Department of Chemical Engineering, died at the age of 88. In 1922 he was appointed Assistant Professor of Chemical Engineering and served on the faculty until his retirement in 1960.

Robert S. Woodbury, Professor Emeritus of the History of Technology, died at the age of 76 in September 1983. With the exception of six years' service in the Navy (1940–1946), he was on the teaching staff of MIT from 1929 until his retirement in 1972.

Statistics for the Year

The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1983–84.

Registration

In 1983–84 student enrollment was 9,577, compared with 9,475 in 1982–83. This total comprised 4,602 undergraduates (compared with 4,619 the previous year), and 4,975 graduate students (compared with 4,856 the previous year). Graduate students who entered MIT last year held degrees from 381 colleges and universities, 227 American and 154 foreign. The international student population was 2,106, representing 12 percent of the undergraduate and 31 percent of the graduate population. These students were citizens of 97 countries.

Degrees awarded by the Institute in 1983–84 included 1,169 bachelor's degrees, 1,162 master's degrees, 72 engineer's degrees, 415 doctoral degrees — a total of 2,818.

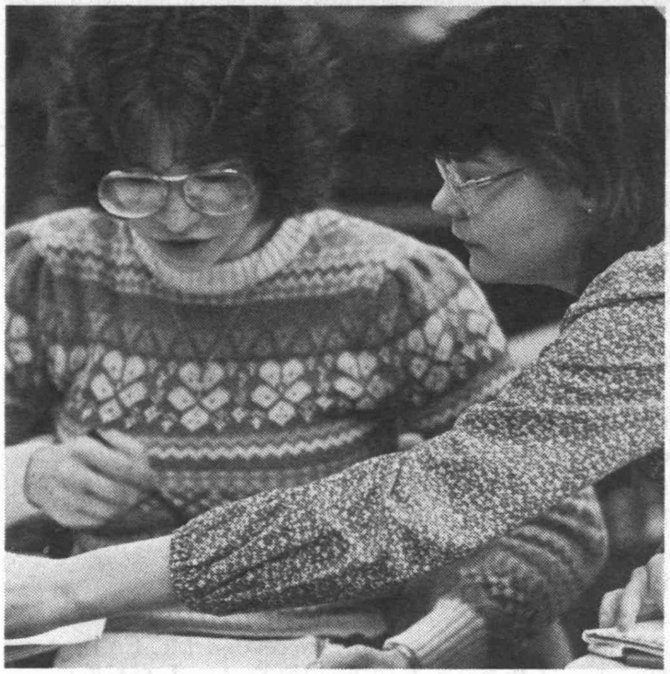
In 1983–84, there were 2,066 women students (1,090 undergraduate and 976 graduate) at the Institute, compared with 1,977 (1,048 undergraduate and 929 graduate) in 1982–83. In September 1983, 259 first-year women entered MIT, representing 24 percent of the entering class.

In 1983–84, there were 1,107 minority* students (914 undergraduate and 193 graduate) at the Institute, compared with 968 (817 undergraduate and 151 graduate) in 1982–83. The first-year class entering in September 1983 included 270 minority students, representing 25 percent of the class.

Student Financial Aid

During the academic year 1983–84 the student financial aid program was again characterized by increases

In 1983-84, there were 2,066 women students at the Institute.



BRADFORD F. HERZOG

in the overall need for financial aid and in the aggregate amount of grants made available.** There was an increase in the amount of MIT loans awarded. Federally guaranteed loans obtained from commercial sources showed a significant decrease.

A total of 2,662 undergraduates who demonstrated the need for assistance (58 percent of the enrollment) received $14,748,000 in grant aid and $2,418,000 in loans. The total, $17,166,000, represents a 16 percent increase in aid compared with last year.

Grant assistance was provided by $3,831,000 in income from the scholarship endowment, by $1,712,000 in outside gifts and federal allocations to MIT for scholarships, and by $3,219,000 in direct grants to needy students. Scholarship assistance from MIT's own operating funds was provided to the extent of $5,871,000 (a 46 percent increase over last year's level and the largest allocation ever). The special program of scholarship aid to minority group students represented an additional $115,000 from specially designated funds. An additional 610 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was aided by the addition of $2,227,227 in new funds, which raised the principal of the endowment to $35,913,417.

Loans totaling $2,418,000 were made to needy un-

*Minority students include 319 Blacks (non-Hispanic), 21 native Americans, 199 Hispanics, and 568 Asian Americans.

**Scholarship and fellowship figures differ slightly from those reported in the Treasurer's Report because of differences between academic and fiscal year accruals.

dergraduates — a one percent decrease from last year. Of this amount $484,000 came from the Technology Loan Fund and $1,934,000 from the National Direct Loan Fund. Not included in the foregoing summary is an additional $5,982,000 obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources. This represents a two percent decrease in the use of these programs over last year.

Graduate students obtained $1,632,000 from the Technology Loan Fund, $304,000 of which was loaned to international students and did not qualify for the federal interest subsidies and guarantees available under the Guaranteed Student Loan Program. In addition, $228,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, $1,860,000, represents a 39 percent increase over last year's level. Graduate students obtained $3,011,000 from outside sources under the Guaranteed Student Loan Program — 13 percent below last year's level. The total loaned by MIT to both graduate and undergraduate students was $4,278,000, a 13 percent increase over last year's level.

Career Services and Preprofessional Advising

Employment opportunities for graduating students were distinctly better in 1983–84 than during the previous year. There was a great increase in the number of job offers reported by companies and by students, even though the number of employers making recruiting visits rose hardly at all, from 405 in 1982–83 to 407 in 1983–84. The number of student interviews also changed very little, hovering near 9,700.

The demand for graduates in electrical engineering and computer science was pervasive. In the spring term alone nearly 300 separate employers asked to see electrical engineers; more than 200 asked for students in computer science. The firms looking for electrical engineers and computer scientists were in almost every industry, from computers and communications to aerospace, chemicals, oil, paper, railroads, and banking.

Fortunately, the vitality of the electronics and computer industries is creating a new demand in other disciplines as well. In 1981–82 more than a third of the Institute's graduates in mechanical engineering joined electronics firms. In 1982–83 the electronics industry was the destination of a quarter of the Institute's chemical engineers and a third of the master's graduates at Sloan. Figures are not yet available for 1983–84 but it is likely that they will tell the same story, probably even more emphatically.

There was a small increase in the number of MIT applicants to medical school, chiefly stemming from an increase in the number of alumni applicants. A total of 105 candidates filed applications, compared with 101 in 1982–83. They included 69 seniors, 3 graduate students, and 33 alumni. Preliminary returns indicate that 55 seniors, all the graduate students, and 19 alumni were accepted.

Thirty-seven MIT candidates applied to law school. As in previous years the majority were alumni (21 out of 37).

Finances

As reported by the Vice President for Financial Operations and the Treasurer, the total financial operations of the Institute, including sponsored research, amounted to $658,611,000, an increase of 12 percent over 1982–83. Education and general expenses — excluding the direct expenses of departmental and interdepartmental research, and the Lincoln Laboratory — amounted to $270,180,000 during 1983–84, compared with $255,541,000 in 1982–83. The direct expenses of campus departmental and interdepartmental sponsored research increased from $149,478,000 to $156,811,000; and direct expenses of the Lincoln Laboratory's sponsored research increased from $183,683,000 to $231,620,000, largely because of increased subcontracts and equipment purchases.

Current revenues used to meet the Institute's operating expenses totaled $651,932,000, augmented by $6,679,000 in unrestricted revenues. After meeting these expenses, a surplus of $805,000 in current unrestricted gifts was held.

The construction program of the Institute continued

Employment opportunities for graduating students were distinctly better in 1983-84 than during the previous year.

BRADFORD F. HERZOG

to make progress in 1983–84, with the book value of educational plant facilities increasing from $288,392,000 to $298,895,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, students' notes receivable, and amounts due from educational plant, had a book value of $605,378,000 and a market value of $771,319,000. This compares to book and market values of $514,808,000 and $767,228,000 last year.

Gifts

Gifts, grants, and bequests to MIT from private donors decreased slightly in 1983–84 to a total of $49,122,000, compared with $50,025,000 in 1982–83. The Alumni Fund reported gifts of $9,434,000 for the year, a new record.

Physical Plant and Campus Environment

One new building, the EG&G Education Center, was completed and occupied during the year. This five-story, 20,000 square foot facility, located between the two wings of the Sherman Fairchild Electrical Engineering and Electronics Research Building, contains a 325-seat lecture hall, four conventional classrooms, a student lounge, an undergraduate teaching laboratory, and a multi-use departmental conference room. Opening of the Center, designed exclusively for teaching and conference purposes, completed a plan conceived more than a decade ago. The building was dedicated on October 7, 1983, in honor of Esther M. and Harold E. Edgerton, Pauline S. and Kenneth J. Germeshausen, and Dorothy J. and Herbert E. Grier, whose joint efforts made the facility possible.

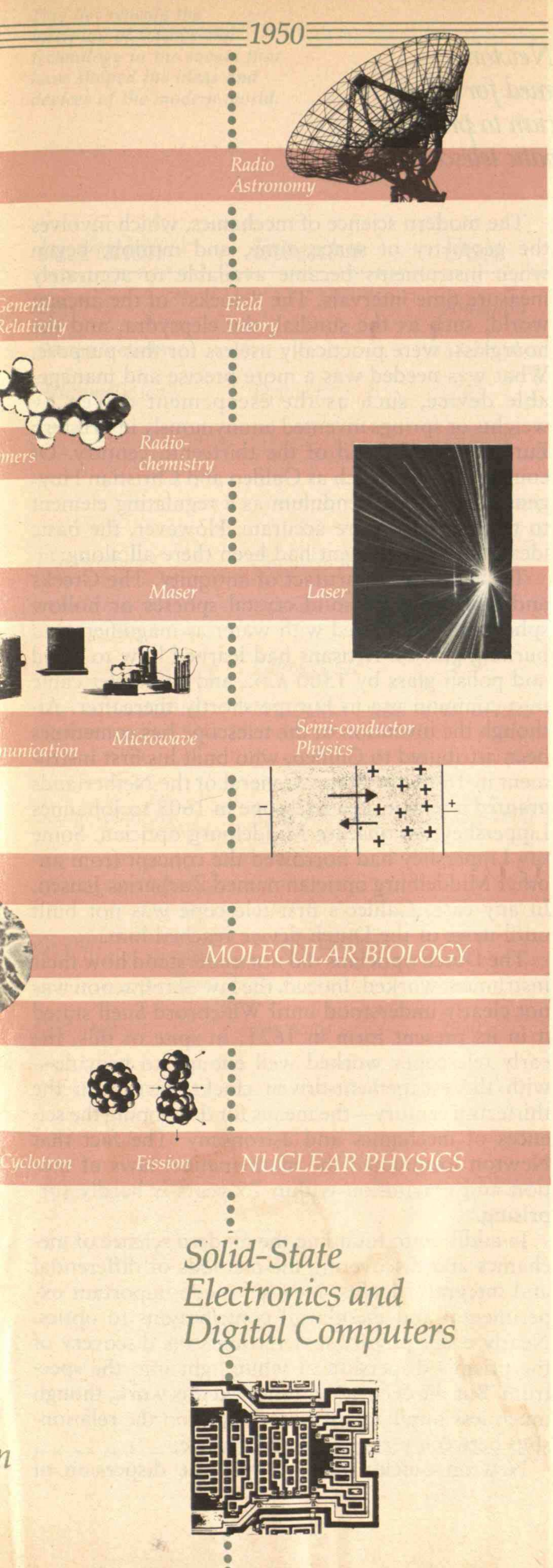
Other projects completed during the year included renewal of the undergraduate chemistry teaching laboratories on the fourth floor of Building 4, renovation of 175 Albany Street to accommodate the Nuclear Magnetic Resonance (NMR) Facility and additional Plasma Fusion Center activities, renovation of the first floor of Building 11 to house the Joint Computer Center and Project Athena and of the basement to accommodate the Graphic Arts Copy Center, renovation of the upper floors of the Sloan Building (E52) for the Sloan School and Department of Economics, and installation of new kitchens and dining areas in the East Campus and Senior House dormitories.

Major projects under construction and scheduled for completion this fall are the Arts and Media Technology facility on Ames Street and the Microsystems Research Laboratories in Building 39 on Vassar Street. The latter facility, scheduled to be made available to the research staff in December, will require up to another year for installation of complex research equipment.

Smaller projects scheduled for fall completion include the Center for Real Estate Development on the top floor of the old Armory Building (W31) on Massachusetts Avenue, the Mechanical Engineering Design Center on the fourth floor of Building 3, portions of the second and third floors of Building 2 for chemistry research laboratories, and a relocation of Amherst Alley on the West Campus between Danforth Street and Burton-Connor House to move the road away from the student residences and create a more attractive and safe environment.

Two major changes in the dining commons program were implemented during this past year. First, East Campus and Senior House residents are no longer required to participate in the program because they now have kitchen and dining facilities within their residences. Second, a la carte service was offered in place of commons at 500 Memorial Drive in response to a student proposal to the Dining Advisory Board. Both of the above changes seem to have been well received by the students in those houses.

For the past several years, the telecommunications industry has been undergoing substantial changes, which are reflective of new technology, increased usage of networked computers, and regulatory actions. Because of these changes, we have undertaken an evaluation of the telecommunication services for the Institute community. Our analysis indicates that the Institute would be better served by a state-of-the-art digital switching system than by the present Centrex system provided by the telephone company. As a result, we released a request to selected vendors in May 1984 asking for proposals to replace the Centrex system with a coherent and integrated telecommunications system capable of transporting all forms of messages (voice, data, video, and facsimile). If we implement one of these proposals, the new system would begin operation in the latter half of 1986.



in outlook and interests between scientists and engineers is broadly true. Most branches of technology trace their ancestry to one or more of the pure sciences—chemical engineering to chemistry, electrical engineering to physics, computer science to physics and mathematics. Countless technological spinoffs have stemmed from advances in pure science. Indeed, there is sound justification for the traditional wisdom that engineers and technologists adapt science to meet human needs.

Scientists have good reason to be proud of the useful technology that has developed in the wake of fundamental scientific advances. The work of James Clerk Maxwell and Heinrich Hertz in establishing the possibility of communication using radio waves, that of William Shockley, John Bardeen, and Walter Brattain in developing solid-state electronics, and that of Charles A. Townes and Arthur Schawlow in inventing the laser are but a few of the more obvious examples of this relationship between science and technology.

Instances of the reverse process are harder to discover. For though engineers have sometimes succeeded better than scientists in publicizing their achievements (many people think Guglielmo Marconi rather than Hertz "invented" radio communication, for example), the history of science and technology has by and large been written by scientists. Many of these chroniclers have been slow to credit the role of technology in spurring the growth of pure science.

The oft-neglected fact, however, is that the development of pure science has not infrequently been enhanced by technological innovation involving little or no scientific input. Yet today our science and technology enterprise is highly structured around the conventional wisdom that technology's role is to capitalize on scientific results for human use. And while we continue to pursue new science and technology according to this paradigm, we must ensure that the contributions of technologists are as enriching to science in the future as they have been in the past.

Setting the Stage for Electromagnetism

Hans Christian Oersted's discovery of the magnetic field associated with a current of electricity is an excellent example of a technology-driven scientific discovery. It was in 1819 that Oersted found that

Because Newton was wrong, it remained for a largely self-educated optician to produce successful achromatic telescopes.

the needle of a compass deflects when an electric current passes through a coil surrounding the device. Why 1819? Because by then it was possible, using "voltaic cells" (batteries), to set up a steady electric current in a circuit. The voltaic cell, however, was a purely technological innovation based on very little scientific understanding. Its origin lay in the discovery by the physiologist Luigi Galvani in 1786 that the muscles in the legs of dead frogs contracted when placed in a circuit containing dissimilar metal electrodes and an electrolyte. Galvani attributed this to an effect he called "animal electricity."

However, Alessandro Volta soon challenged this idea, suggesting that "galvanic action" was due to the contact between dissimilar metals. Although more reasonable, this idea was equally incorrect. Even so, in 1800, Volta succeeded in making a reliable battery using discs of dissimilar metals separated by pads moistened with a saline electrolyte. Though a good scientist, Volta did not understand that the action of his cells depended upon a chemical reaction and the transport of ions through the electrolyte. In fact, not until 40 years later did Michael Faraday correctly explain how this battery worked. Thus, galvanic action and the electrolytic cells that used it were discovered purely by experimentation, guided hardly at all by science. Because of these advances, however, Oersted had everything he needed to discover the magnetic field surrounding a conductor in 1819.

Similar examples in the history of science are more common than usually supposed. In seeking them out, it is often useful, as in the case of Oersted's experiment, to inquire about why a particular scientific development occurred when it did.

Measuring Time and Seeing the Unseen

There is ample evidence, for example, that the intellectual ferment that began near the end of the fifteenth century brought forth both the spirit of inquiry and the rational mindset that produced the discoveries of Nicholas Copernicus, Tycho Brahe, Johannes Kepler, Galileo Galilei, and Sir Isaac Newton. Accordingly, historians usually trace the origins of modern science to the Renaissance. However, this era of discovery was also made possible by two simple devices invented much earlier and for which science can claim little or no credit. They are the clock and the lens.

The modern science of mechanics, which involves the geometry of space, time, and motion, began when instruments became available to accurately measure time intervals. The "clocks" of the ancient world, such as the sundial, the clepsydra, and the hourglass, were practically useless for this purpose. What was needed was a more precise and manageable device, such as the escapement driven by weights or springs invented anonymously in Western Europe near the end of the thirteenth century. Of course, scientists such as Galileo and Christian Huygens adapted the pendulum as a regulating element to make clocks more accurate. However, the basic idea of the escapement had been there all along.

The lens was an artifact of antiquity. The Greeks and Romans used solid crystal spheres or hollow spherical vessels filled with water as magnifiers and burning glasses. Artisans had learned how to grind and polish glass by 1300 A.D., and spectacles came into common use in Europe shortly thereafter. Although the invention of the telescope has sometimes been attributed to Galileo, who built his first instrument in 1609, the States-General of the Netherlands granted a patent on a telescope in 1608 to Johannes Lippershey, an obscure Middelburg optician. Some say Lippershey had borrowed the concept from another Middelburg optician named Zacharias Jensen. In any case, Galileo's first telescope was not built until news of the Dutch device reached him.

The Dutch opticians did not understand how their instrument worked. Indeed, the law of refraction was not clearly understood until Willebrord Snell stated it in its present form in 1621. In spite of this, the early telescopes worked well enough to provide—with the escapement-driven clocks devised in the thirteenth century—the means for developing the sciences of mechanics and astronomy. The fact that Newton formulated the mathematical laws of motion and gravitation within 75 years is hardly surprising.

In addition to founding the modern science of mechanics and discovering the methods of differential and integral calculus, Newton made important experimental and theoretical contributions to optics. Nearly every physics text recounts his discovery of the prism's dispersion of white light into the spectrum. But the events that followed this work, though much less familiar, shed more light on the relationship between technology and science.

Newton quickly realized that the dispersion of

This list reveals the interplay of science and technology in the events that have shaped the ideas and devices of the modern world.

Invention	Inventor	Date
Lens		Antiquity
Accurate clocks		Medieval
Achromatic lens	Dollond	1757
"Conventional" optical devices using mirrors and lenses	Abbé, Gauss, Petzval, Rudolf, et al	1800s
Zone plate	Fresnel	~1830
Photography	Daguerre et al	~1830
"Conventional" electro-technology	Faraday, Henry, et al	~1835
Incandescent lighting	Edison/Swan	1879
Internal combustion engines	Benz, Otto, Diesel	1870–1900
Radio communication	Hertz/Maxwell	1887
Sound recording	Edison/Berliner	1889–1900
Interferometer	Michelson	1890
Cathode ray tube	Thomson	1897
Aircraft	Wright Brothers	1903
Triode vacuum tube	De Forest	~1907
Cyclotron	Lawrence	1930
Fluorescent lighting	Inman et al	1938
Computers	Bush, von Neumann, et al	1940–1950
Antibiotics	Fleming	~1940
Nuclear reactor	Fermi	1942
Transistor	Shockley et al	1948
Maser/laser	Townes/Schawlow	1950s

Science — Technology

light was responsible for the poor imaging qualities of the refracting telescopes then available. This is because simple lenses refract light of different colors to different focal points, producing images surrounded by color fringes. These fringes severely reduced the resolving power of early telescopes. Newton sought to eliminate this effect by combining converging and diverging lenses. However, some of his experiments suggested that the refractive and dispersive powers of transparent substances were always proportional, and he therefore concluded that this method of eliminating color aberrations would do away with the telescope's net magnifying capability as well. Newton therefore abandoned work on refracting systems and turned his attention to reflectors, which do not disperse light. His efforts culminated in the development of a satisfactory reflecting telescope in 1671, which is even now after more than 300 years referred to as the Newtonian reflector.

Unfortunately, however, Newton was wrong when he concluded that it was impossible to build a refracting telescope that would not exhibit chromatic aberration. His error impeded the progress of optical science for almost a century. In 1733, an astronomer named Chester Moor Hall found that two refractive elements could in fact be coupled in such a way as to nearly eliminate the color fringes associated with single lenses; but Hall failed to publish any account of his more or less accidental discovery. So it remained for a British optician, John Dollond, to repeat Newton's experiments on refracting substances. Dolland found that Newton's conclusions were incorrect because of an unfortunate choice of experimental samples and because his measurements were not very precise. Emboldened by this finding, Dollond succeeded in 1758 in producing achromatic telescopes of excellent quality—work for which he was awarded the Copley Medal of the Royal Society.

This story is of interest because Dollond was an optician, largely self-educated—not an astronomer or a physicist. He and his son made optical instruments. His excitment at having shown Newton's ideas to be incorrect can only be imagined, but he could hardly have conceived of the larger significance of his work. By 1800, Dollond's methods had been successfully applied to the design of microscope lenses that formed images much clearer and sharper than ever before. This development soon led to the

discovery of the cellular structure of plant and animal tissues, and to the growth of the sciences of cytology, microbiology, and immunology during the first half of the nineteenth century.

Similarly, the photographic process is one of technology's outstanding gifts to science. It would be gratifying for a physicist to report that photography was made possible by scientific understanding of the action of light on silver halide crystals. But this is simply not the case. The photographic process was introduced in 1839 by Nièpce, Daguerre, and Fox-Talbot as the result of a process of trial and error by artists, artisans, chemists, inventors, and amateurs of every conceivable sort, abetted by scientists of many different backgrounds, including James Clerk Maxwell, who made the first color photograph in 1861. Though by 1870 the photographic process had evolved into a useful and versatile technology, none of its inventors had even then much understanding of the physics and chemistry on which it was based. Indeed, some of these processes are still not clearly understood today.

Incandescent Lighting and Vacuum Tubes

In contrast, the technologies of electricity, magnetism, and electronics owe a great deal to pure science. Indeed, most common circuit elements and simple electrical machines—electromagnets, inductors, capacitors, dynamos and motors, induction coils and transformers, transmitters and receivers of radio waves, and instruments for measuring current, voltage, and resistance—are the direct result of the work of scientists. Among those involved were Oersted, André Marie Ampère, Michael Faraday, Joseph Henry, Sir Charles Wheatstone, Wilhelm Weber, Lord Kelvin, Maxwell, and Hertz. Some of these scientists doubled as electrical engineers before that discipline was established in its own right around 1880. The technology of electrochemistry arose primarily from research by the physicist Michael Faraday. The work of physicists such as William Crookes, J.J. Thomson, Owen Richardson, Irving Langmuir, and John Townsend was fundamental to electronics, and more recently scientists such as Shockley, Bardeen, Brattain, and Walter Schottky founded solid-state electronics.

Yet striking examples of the inverse process—in which science contributes little and cut-and-try experimentation a great deal—can be found even in this field. Electric lighting is one case. Early efforts to produce satisfactory incandescent lamps failed because filament materials and the vacuum technology were inadequate. These difficulties were finally surmounted by Thomas Edison, who developed a practical incandescent light in 1878. Joseph Swan, working independently in England, also invented an incandescent lighting system at almost the same time.

Edison, perhaps the quintessential technologist, lacked formal education. His understanding of literature, art, history, and philosophy was superficial, and—despite the fact that he had invented the phonograph and founded a recording company—his musical taste was abominable. He is therefore sometimes regarded with disdain by academic scientists, who often forget that his ingenuity, inquiring spirit, and tireless efforts contributed significantly to many disciplines. Edison mastered the fundamentals of electricity and magnetism and became a creative and wide-ranging experimenter. He was the first to describe the thermionic current that could be made to flow between an incandescent filament, such as that in his electric light bulb, and an auxiliary "plate" placed within the evacuated bulb—a "diode." This work opened the way for the later scientific achievements of Wilhelm Röntgen, Childs, Richardson, and Langmuir. All thermionic devices are, after all, descendants of Edison's incandescent lamp.

In a somewhat similar scenario, Lee de Forest stumbled upon his "audion," or vacuum-tube triode, in 1906—a development that was to revolutionize communication. J.A. Fleming, professor of electrical engineering at the University of London and advisor to the Marconi Wireless Telegraph Co., had just developed a high-vacuum diode detector of radio waves for wireless communication. This dectector used the unidirectional current that Edison had observed 20 years earlier. Fleming correctly ascribed this current to a flow of electrons; indeed, it was he who introduced the word *electron* into the English language to describe the particles referred to by J.J. Thomson, their discoverer, as "corpuscles."

De Forest began a search in 1904 for a system of wireless communication that would not be covered by patents taken by Marconi on Fleming's device. His early attempts duplicated some of Fleming's work, though he did not understand that the currents he utilized were electronic rather than ionic or molecular in origin. When de Forest finally tried inserting a "grid" electrode between the filament and

The result of World War II was a research enterprise based upon the idea of science as the driving force for technology.

plate of an Edison-Fleming diode, he made the landmark discovery that the flow of current in the plate circuit could be controlled by a signal applied to the grid. He described his "audion" in a vague and discursive paper presented to the American Institute of Electrical Engineers on October 26, 1906, and filed a patent on the device and its circuitry in 1907.

The importance of this development did not immediately dawn upon the technical community. But de Forest's patent was finally acquired by Bell Telephone Laboratories, where efficient and reliable triode tubes were soon developed to perform a wide variety of communications functions. The resulting devices included radio transmitters and receivers, audio amplifiers, and a long list of valuable scientific instruments such as electrometers, photodetectors, particle counters, timing circuits, oscilloscopes, and, ultimately, digital computers.

The cyclotron, invented by Ernest Lawrence in 1930 to accelerate protons and other charged particles, was a contraption developed by a scientist for scientific purposes if there ever was one. But why 1930? Because the cyclotron is basically a big vacuum tube—one that relies, moreover, upon a powerful radiofrequency transmitter to excite the particles. By 1930, de Forest's "audion" technology had developed to the point where these elements were readily available, and Lawrence had no trouble finding the hardware needed to build his accelerator.

The relationships between scientists and technologists were informal and sometimes quite accidental in these historical examples. Each group influenced the other without any specific plan to do so. Such a relationship persisted for centuries, changing only around 1900, when a few companies such as AT&T, General Electric, Westinghouse, and du Pont established good research laboratories. Important government facilities such as the National Bureau of Standards in the United States and the National Physical Laboratory in Britain were also set up about that time. In these laboratories research proceeded along well-defined disciplinary paths that put engineers in the role of consumers of scientific understanding.

Centralizing the Scientific Endeavor

This pattern suddenly changed during World War II in response to demands for highly sophisticated weapons and defense systems. These needs had to be satisfied very quickly, and meeting them required both new science and new technology. Ideas at the forefront of scientific research had to be applied immediately. Huge laboratories and production facilities grew up almost overnight.

Under these sharply changed circumstances, engineers and scientists had to work and even live together, and they often had to do each other's jobs. Disciplinary lines usually meant little or nothing. Because the projects were large and their goals vital, research and development was planned and administered on an unprecedented scale. But still it was anticipated that scientific advances would provide the foundation for new technology.

This paradigm was strongly reinforced by the success of these activities as their programs were reorganized after the war. The result was a science and technology enterprise much more centralized and structured than ever before. Government funding and planning of research and development and even of scientific and technical education became the norm. Universities, industries, and private research institutes found themselves at once in close cooperation and also in earnest competition for the federal dollar. This situation wasn't restricted to the United States; it also prevailed, to greater and lesser degrees, in other Western nations. Essentially all these programs were based upon the paradigm of science as the driving force for technological innovation.

An End to Edisons?

How has this new structure affected the ability of the independent, self-educated technologist to contribute in the tradition of Lippershey, Edison, and de Forest? The perspective of time will be needed to answer this question fully. However, it is not too soon to make some preliminary observations.

Our present highly centralized system has succeeded beyond expectation in promoting science-driven technology. Recent advances in microlectronics, optical communications, computing, and genetic engineering are obvious examples. The inverse process—wherein technology returns new resources for advances in pure science—is also thriving. Recent advances in computer simulation, for example, are important in aiding basic scientific research.

A less satisfactory result of the highly structured R&D effort is that risk taking is not encouraged. All

Help for Tinkerers

BY WIL LEPKOWSKI

EVEN in Washington, where conventional wisdom is deeply entrenched in policy, the old myth about technology as the application of scientific results is giving way to a more enlightened view of a complex interrelationship. Indeed, the science-technology interface is currently topical, even bordering on the chic.

Says senior policy analyst Christopher Hill of the Congressional Research Service, "I think technology's driving of science is an important policy issue because it makes nonsense of the idea that science is driven only by its own ideas. The practical areas were always important. I think we'd be surprised by the amount of Nobel Prize research that was undertaken with the aim of a practical outcome."

Adds M. Kent Wilson, deputy assistant director for mathematics and physical sciences at the National Science Foundation (NSF), "There's no question that in chemistry and materials science, new technology embodied in instruments has enabled us to measure things we weren't able to measure before. So in that sense, technology has been driving science. Nuclear magnetic resonance (NMR)—the use of nuclear resonances to clarify the structures of complex molecules—is the obvious technology that comes to mind. In materials research, we're answering questions we couldn't even ask a few years ago because of NMR instrumentation."

But the possible results of this changing view of the role of technology with respect to science are still unclear. For the immediate future, at least, no grand policy changes seem likely.

On the other hand, Washington is beginning to assess how budgets and policies might be changed to support technology independent of science. This issue is part of the lively debate about the need for new funding for academic instrumentation and facilities, the persistent claims that the peer-review system stultifies risk taking, the new orientation toward engineering research at the NSF, and the decision to establish the relatively new Small Business Innovation Research Program, administered throughout the government's research agencies.

New Ways of Funding

What has more recently set the avante garde of the Washington science-policy community talking is the concept of science's "instrumentalities," credited to the late science historian Derek de Solla Price of Yale University. Before he died last year, Price left an article on the science-technology relationship to be published in *Research Policy*; it is now being widely circulated as a basis for new thinking about research funding.

In brief, Price said that we have tended to overlook the role of technology in opening up new areas of scientific thought and experimentation. He avoided using the word "instruments" to describe this process, because that would limit the phenomenon to hardware. Price was thinking more in terms of the power of instruments and researchers combined to advance science in important ways, and to this combination he assigned the term "instrumentality."

Price argued that science now depends so much on its instrumentalities that current patterns of funding no longer reflect its real needs. He therefore suggested that federal agencies concentrate on funding the instruments needed to do research rather than salaries in their granting system. Price cited several nations where policymakers have concluded that it is inappropriate to "buy research labor from people who already have useful jobs."

This proposal leaves unsolved another major problem: how to encourage scientists and engineers to invent new instruments, or even to purchase used ones for rebuilding into novel devices. "The people funding research," admits one NSF staffer, "have no policy to encourage such 'tinkering'."

It's doubtful that the Washington science-policy community will develop a "tinkerer policy" anytime soon. For most problems, this approach doesn't seem to pay off. But if one of the dozens of advisory committees to the various agencies decided that tinkerers need support, a "demonstration program" could be launched quickly.

The $4 Billion Genie

For science-policy watchers, the problem of keeping research and teaching equipment—the "infrastructure" of universities—up to date is one to keep an eye on for the next year or so.

Former science adviser Edward E. David, currently president of Exxon Research & Engineering Corp., says the new instruments and equipment U.S. universities now need would cost $4 billion. Federal funding for such equipment so far totals only about $400 million, and that covers just the purchase of new items, not their upkeep and improvement.

The Office of Management and Budget wants to keep this genie in its bottle. As one OMB official put it, every university can make a legitimate claim for new facilities, and "we just don't want to open that can of worms. The budget couldn't stand it." Perhaps the problem is better solved in smaller bites. The NSF now thinks that 24 percent of the average research grant in mathematics and the physical sciences goes for equipment. Ten years ago it was more like 10 percent.

Some scientific societies are planning to urge that Congress and the administration establish a separate "ministry" for instrumentation—an interagency office that would scout out future needs for research technologies and coordinate funding. Universities are also seeking such unconventional methods of meeting instrumentation needs as debt financing, increasing tax incentives for donors, and changing federal regulations to allow research funds to be used for such purposes. The Association of American Universities will soon issue a report on these suggestions.

Such thinking opens a new understanding of "the whole role of the instrumentation industry in linking science, technology, and industrial development," says William Blanpied of the NSF. "It also changes science's internal set of values." Blanpied hopes to study in some detail the effects of advances in instruments on advances in science. How, for example, has laser technology motivated chemists to achieve significant advances in molecular theory?

Perhaps the major dilemma in resolving these questions is that if the system is going to work, scientists have to continue to believe that they drive technology. Must the corollary be that technologists master the technique of false flattery? □

WIL LEPKOWSKI is senior editor of Chemical and Engineering News.

In the environment of safe science and homogeneous technology, the role of the self-educated amateur inventor is rapidly vanishing.

the planning and funding of basic science provided since World War II have not changed its intellectual framework to the same extent as, say, the discovery of relativity and quantum physics did in prewar years. Today's scientific work is sophisticated, arcane, complex beyond belief—but safe. One does not, for example, try to discover whether quantum physics has its limitations, and if so where they lie. It simply doesn't pay to do so.

Similarly, though private technological entrepreneurship is flourishing, it lacks the diversity of earlier times. It is less easy now than it was 50 or 100 years ago for technologists like Edison—or scientists like Einstein, I might add—to assert their independence. Experimental high-energy physics, for example, requires an incredibly complex grid of technologies, including electronics, nuclear technology, magnetics, cryogenics, new materials, high vacuum, and advanced computers. Committees plan research 20 years ahead based on the commitments of machine designers and builders to complete new accelerators.

In this environment the role of the self-educated amateur inventor—the Edisons and de Forests—is rapidly vanishing. To be funded as a technologist now, you need not only a fertile imagination and the capacity for hard work but also formal education, preferably on the graduate level. Published research is often credited to dozens of authors and describes the activities of teams containing hundreds of members. Work is organized, directed, and funded by the cooperative—and competitive—efforts of numerous individuals, none of whom enjoy the luxury of complete freedom of thought, and all of whom have more stake in its outcome, personally and professionally, than is desirable. Finally, when a Nobel Prize is given it usually goes to a scientist rather than to a technologist! The exceptions to this trend, such as the work of Stanford Ovshinksky in developing amorphous semiconductor materials and devices, are so few as to prove rather than call into question the trend.

Under these conditions, the relationship between science and technology, though of great mutual benefit, is not entirely smooth and peaceful. Indeed, there is a polite but earnest power struggle for prestige between scientists and technologists. Both are reluctant to acknowledge this conflict, but its reality can be confirmed by anyone who has competed for federal funding or public recognition in the science-technology arena. This phenomenon, born to a large extent of the postwar circumstances of science and technology, is a threat to the future viability of the independent, self-educated technologist. Indeed, this polite, clandestine power struggle for resources and recognition will probably intensify, and there is little likelihood that we will return to the casual, unplanned, informal relationships of earlier and gentler times.

Throughout the history of science, the unplanned and unexpected has been as important as what is confidently sought and accurately predicted. And now, as in the past, technology is driving science as fast as it is being driven by science. But the opportunities for the individual technologist are not as great as in Edison's and de Forest's times. We need to recall—and foster when we can—the special circumstances from which came such signal advances as the telescope, the incandescent lamp, and the vacuum tube. Perhaps we should insist that our planners devote resources to a few "obviously" unsound projects and "clearly" unprofitable lines of thought, or that they encourage individual investigators as well as organized groups, however "wasteful" that may seem. Will readers still find examples such as those discussed above a hundred years from now, as they look into the story of scientific and technological progress in the last half of the twentieth century and the opening years of the new millennium?

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The Healing Touch of Artificial Skin

BY THOMAS H. MAUGH II

MARK WALSH achieved a fame that, given the chance, he would just as soon have avoided. On October 22, 1981, the 25-year-old, red-headed electrician was working at an aerosol factory in suburban Boston when an explosion and fire burned nearly 80 percent of the skin off his body. Four others died in the fire, but Walsh was lucky. He was transferred to Massachusetts General Hospital, where Dr. John F. Burke used an artificial skin developed by Ioannis V. Yannas of M.I.T. to close his wounds and, undoubtedly, to save his life.

Walsh was not the first person to receive the synthetic skin, although he was one of the most severe cases. He is, however, the only one of Burke's patients who has chosen to tell his story publicly. His needs, as well as those of others like him, are why Yannas and other investigators are working so hard to develop skin replacements that can be used to save the lives and prevent the disfigurement of severely burned victims.

Walsh was one of an estimated 130,000

PHOTOS: DENNIS P. ORGILL

On a microscopic scale, artificial skin resembles the real thing (insert).

"Several patients would probably have died without the artificial skin."

people hospitalized in 1982 because of burns. In the hospital, the most important immediate goal is to cover the burn quickly, both to inhibit infection and to prevent fluid loss. Some 10,000 individuals die each year from such effects. The ideal covering is an autograft of the patient's own skin: intact skin is removed from an unaffected area of the body and placed over the wound. But Walsh, like most severely burned patients, did not have enough unaffected skin to meet this need.

Physicians can also apply allografts—skin from cadavers. But such skin is generally in short supply and there is a persistent problem with graft rejection. Heterografts of skin from animals—typically pigs—can also be used, but the skin must be removed between three and nine days after application. Even if this technique prevents infection and loss of fluid, shrinkage and scarring of the wounds can still produce substantial disfigurement.

Walsh was fortunate that some of Yannas' artificial skin was available, as supplies are limited. Four days after the fire, he underwent the first of six operations that lasted a total of 24 hours over four days. Burke first cut away all of the burned flesh and fat. He then used as much of Walsh's own skin as he could harvest to begin covering the burns, as well as about nine square feet of the artificial skin to cover Walsh's neck, chest, abdomen, and arms. (The areas that yielded the unharmed skin eventually healed.)

The artificial skin, which looked like strips of moist, smooth, elastic paper towel, was draped over the wounds and sutured in place. Walsh was then wrapped in bandages like a mummy, with only his eyes and nose visible. He remained in a coma for more than two months.

Two Types of Skin

Despite its seeming simplicity, the skin that Walsh had lost was a large and complex organ. In an average adult, it weighs one and a half pounds and has a surface area of almost 20 square feet. Its thickness varies from about one-twenty-fifth of an inch over the eyelids to as much as three-twenty-fifths of an inch on the back, palms, and soles. Its main functions include temperature regulation, sensory input, synthesis of vitamin D, and protection from a wide variety of potentially injurious chemical, physical, and biological insults.

Mammalian skin consists of two distinct layers. The innermost is the dermis, a rather dense network of fibrous connective tissue carrying blood vessels, nerves, sweat glands, and hair follicles. The thin (about 1/250 of an inch) outer layer is called the epidermis and is itself composed of several layers.

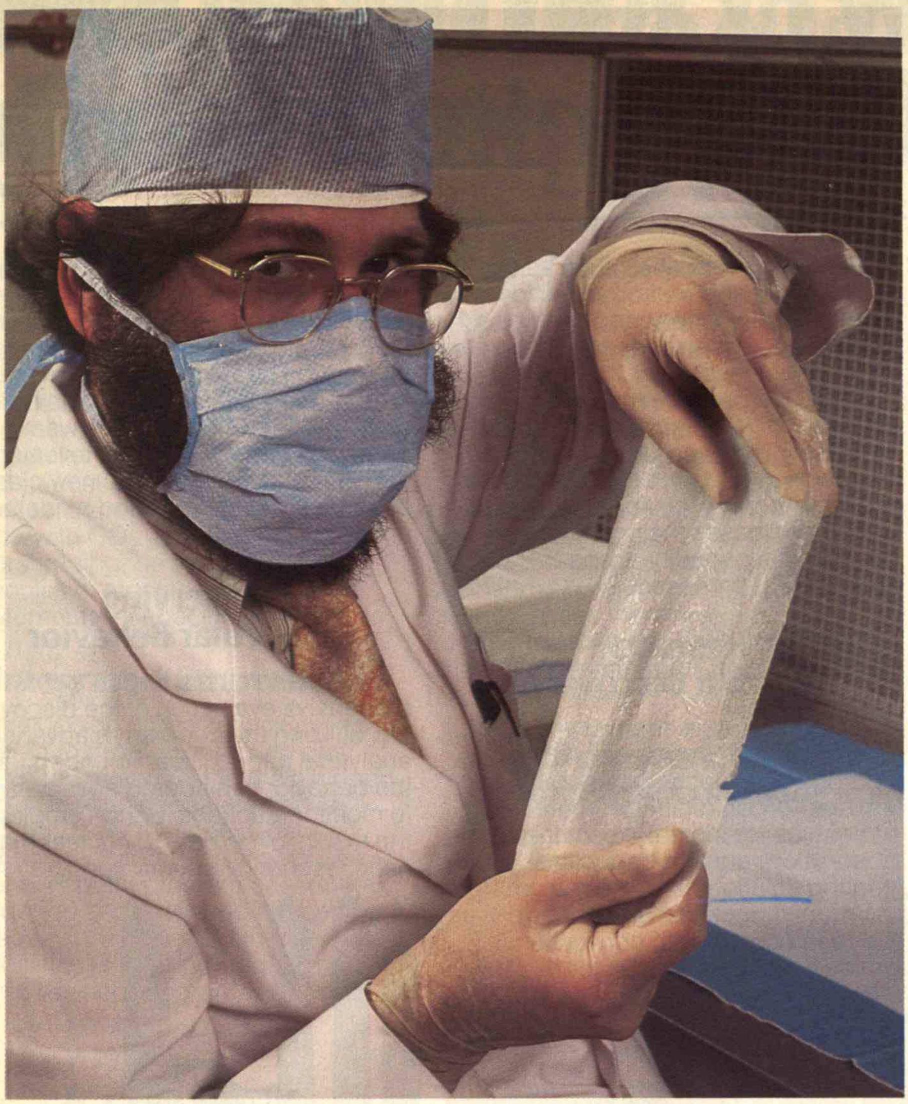
The most important of these is the basal-cell layer, which rests on the dermis. As cells in this basal layer proliferate, they are continually pushed toward the surface. During this passage, the cells undergo a sequence of changes in which they die and their proteins become transformed into the tough, chemically inert, fibrous protein called keratin. The dead cells are eventually shed from the surface as microscopic flakes.

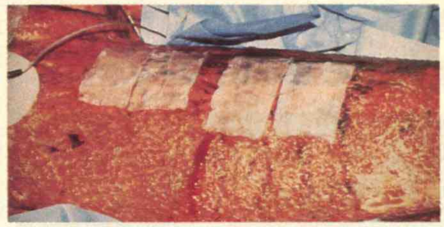
A mild burn, such as a sunburn, affects only the outermost layers, and the epidermis quickly regenerates itself. If the basal-cell layer is destroyed, however, the skin can renew itself only by the inward growth of cells from the periphery. If the wound is smaller than a half-dollar, the skin regenerates itself without appreciable damage. If it is larger, the ingrowth of cells contracts the wound; then, the cells of connective tissue from the subdermal layer, known as fibroblasts, migrate to the wound and produce tough, fibrous scar tissue. It is this process that Burke was attempting to stop in Walsh.

The artificial skin Burke applied to Walsh was the first of two types—Stages 1 and 2—developed by him and Yannas. The key component of both is a template constructed from a highly porous polymer of collagen fibers obtained from cowhide. The polymer is chemically linked to chondroitin-6-sulfate, a major polysaccharide of cartilage that Yannas obtains from sharks; this substance delays breakdown of the polymer by the body. In Stage 1, this polymer is covered with a sheet of medical-grade silicone rubber that both serves as a barrier to infection and fluid loss and provides mechanical strength when the graft is sutured into place.

After Walsh's graft was laid down, fibroblasts began to migrate into it and make more collagen, synthesizing a new dermal layer that Yannas calls a "neodermis." Epidermal cells also began to grow inward from the edge of the graft. The original lattice, meanwhile, slowly biodegraded.

After about 20 days, the silicone layer was removed and small patches of epidermis from elsewhere on Walsh's body were transplanted over the surface of the neodermis. This procedure is much less traumatic than an autograft because none of the deeper-seated dermis is removed. New epidermis grows back over the source area in 7 to 10 days,





Two types of artificial skin grafts have worked in human patients. At left, M.I.T.'s Eugene Skrabut handles sheet of Stage 1 skin, used successfully on about 50 patients. Photos above show two stages in grafting skin grown in culture. At top, four small grafts have been placed on a child's severely burned thigh. After three weeks (bottom), the grafts have taken and have started to grow together.

Yannas says, "rather like a sunburn healing."

When Walsh awoke two days after New Year's, he had no memory of events since the fire. When his bandages were removed, he saw bright healing areas of ruddy pink skin. He was able to distinguish heat and cold and to experience pain in the regenerated area. The main difference between his new and old skin was that the neodermis lacked hair follicles and sweat glands. (The pigmentation of the neodermis matches the patient's own skin coloration.)

Walsh required several months of therapy to regain use of his stiffened joints, but his appearance now is much as it was before the accident. The artificial skin has fulfilled its two main purposes: in the short run, it prevented fluid loss and infection, and over the long run it has given Walsh a skin that behaves like normal skin and enables him to look like himself.

Burke has used the Stage 1 skin successfully on 48 severely burned patients ranging in age from 3 to 85. "Several of these would probably have died without the artificial skin," says Yannas. "Burke is very pleased and his main complaint is that my students don't have time to make a lot more of the material."

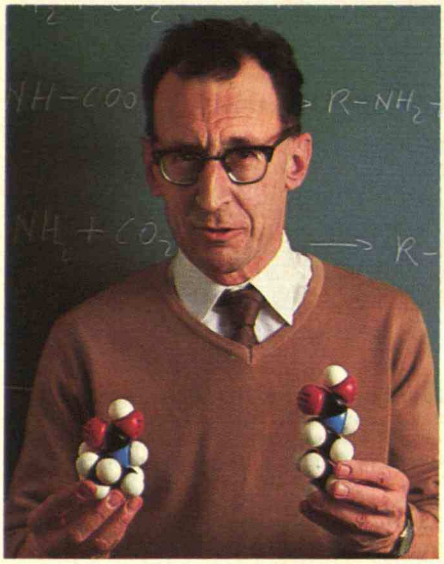
That problem should be easing soon, however. The M.I.T. patent for Stage 1 has been licensed to Marion Laboratories, Inc., of Kansas City, Mo. Marion has obtained permission from the U.S. Food and Drug Administration to begin clinical trials with it, but the trials have been slowed by difficulties in scaling up production from laboratory to commercial quantities. Marion will not comment publicly on its difficulties, but Yannas characterizes them as "typical-technology transfer problems." Clinical trials on burn patients should begin at three institutions shortly.

Meanwhile, Yannas, Burke, Eugene Skrabut, and Dennis Orgill have been working on a more advanced skin called Stage 2. The basic structure of this material is the same as that of Stage 1. In Stage 2, however, the investigators take a small biopsy sample of skin from the potential recipient and isolate basal cells. These are then seeded into the polymer network by centrifuging. A biopsy only the size

PHOTOS: IRA WYMAN, SYGMA; DR. GREGORY GALLICO, MASSACHUSETTS GENERAL HOSPITAL

How Exxon developed
can double the productivity

Guido Sartori's work on hindered amines may impact an entire industry.



Removing impurities such as carbon dioxide and hydrogen sulfide from natural, refinery, and synthesis gases is an expensive, energy-consuming process.

But at Exxon Research and Engineering Company a new chemistry discovery, and cross functional teamwork, have led to the development of a new technology–one that significantly decreases the cost and increases the capacity of commercial gas treating processes.

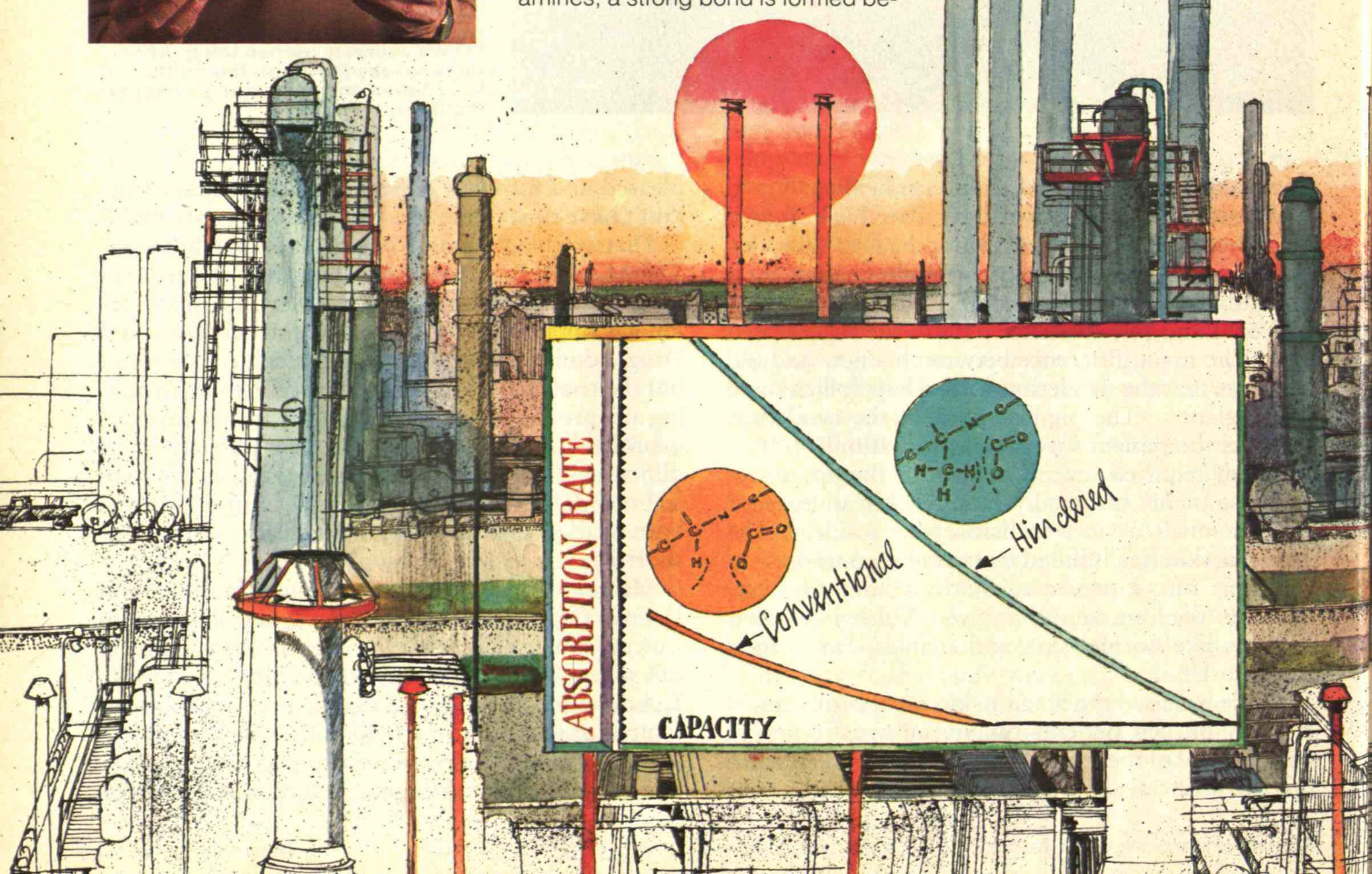
Research Led to a Discovery

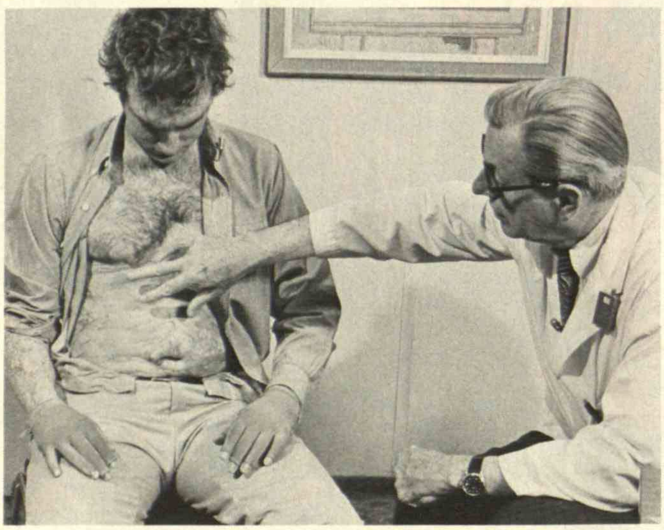
Guido Sartori, a chemist in Exxon Research and Engineering Company, had been conducting research on amines–organic nitrogen-containing molecules–to increase both the absorption rate and capacity of gas treating solutions.

When impurities, such as CO_2, come in contact with conventional amines, a strong bond is formed between the CO_2 and the nitrogen atom of the amine. This strong bond ties up a disproportionate amount of useful amine. Sartori theorized that both the absorption rate and capacity of the amine would be improved if the bond at the nitrogen site could be weakened. Continuing research revealed the advantages of a whole new class of amines, which he called hindered amines.

Observing Molecular Behavior

Sartori and others began a comprehensive evaluation of the discovery, utilizing the company's advanced analytical capabilities. To understand the behavior of hindered amines, and to monitor reactions, Sartori employed the results of carbon-13 nuclear magnetic resonance spectroscopy, a





Two surgical successes emerge after extensive grafts of artificial skin. Glen Selby (top) leaves the Shriners Burn Unit of Massachusetts General Hospital about a year after losing more than 80 percent of his skin in a fire. He received extensive grafts of cultured artificial skin. Bottom: Dr. John Burke of MGH points to artificial skin he grafted onto Mark Walsh's abdomen, after the electrician survived an explosion and fire in an aerosol factory.

of a quarter provides enough basal cells to cover an entire guinea pig with minimal scarring and trauma.

The seeded material is then sutured over the wound. "There is no culturing of the cells, as is the case with some other skin substitutes, so there is no delay in covering the wound. The whole process of seeding takes less than two hours," says Yannas. As with Stage 1 skin, fibroblasts form a neodermis, but the basal cells also proliferate to form a new epidermis. "By day 14 after the graft, the epidermis is confluent, which is very desirable clinically, and the silicone layer can be removed. By day 30, there is almost intact skin."

Again there are no hair follicles or sweat glands, but the new skin otherwise strongly resembles the old skin next to it. "One of the major achievements," says Yannas, "is that we have separated the contraction process from the scarring process. Our findings also contradict statements that the dermis does not regenerate. In this case, it does—at least partially." Yannas and Burke hope to begin clinical trials with Stage 2 skin some time within the next few months.

Trying to Imitate Nature

While Yannas has been developing his artificial skin, Eugene Bell and his colleagues at M.I.T. have been trying to make a bilayered "skin equivalent" that is produced more as natural skin is grown. "If one wishes to make skin," Bell argues, "one would do well to imitate nature."

The first step in Bell's procedure is to obtain a small biopsy of skin containing epidermis and dermis. The sample is cut into small pieces and cultured to obtain fibroblasts. The harvested cells are then added to a solution that contains collagen (obtained from rat tail tendons), rat serum, and tissue-culture medium.

When the acidic solution is made neutral, the collagen comes out of solution in the form of a matrix of fibrils that traps the cells. Under the influence of the cells, the matrix condenses, squeezing out liquid and forming a tissue of firm consistency. Bell calls this tissue a "dermal equivalent."

Bell then performs a second biopsy on the potential graft recipient to obtain a sample of epidermal cells; these are distributed onto the dermal equivalent as a suspension. Within two to four days, the epidermal cells join together in a confluent sheet that

PHOTOS: EMILY LECLAIR, UPI; MASS. GENERAL HOSPITAL

Skin equivalent could be prepared in advance and frozen until needed.

covers the dermal substrate; they also begin to show several characteristics of skin. As soon as the cells link up, Bell drapes the sheet over a wound on the recipient, sutures it in place, and covers it with a bandage. Because the cells are confluent, the wound is sealed immediately.

After nine weeks, such a graft on a rat has become very well developed and has all the charactertistics of normal skin; like that produced by Yannas, however, the new skin has no hair follicles or sweat glands. Blood vessels have fully penetrated the new dermis, but it is still only about half the thickness of the surrounding dermis. Most important, 80 percent of the grafts retain their original shape and size, indicating that the process prevents wounds from contracting.

The main problem with this approach for patients is that it requires 20 to 26 days to prepare an intact skin measuring 100 square inches from each square inch of biopsy material. Bell thinks it may be possible to get around this problem, however, by using skin equivalents prepared from other humans ahead of time.

That technique, though, could encounter the same difficulty as cadaver allografts—the body's immune system may reject foreign cells. This response is governed by proteins, called antigens, on the surface of tissue cells. Each human (and animal) has a unique set of antigens; the individual's immune system recognizes those antigens and ignores cells displaying them, as well as cells that seem to lack antigens. But the system attacks and destroys cells displaying foreign antigens.

Recent research at several laboratories suggests that there are two different types of antigens. Class I antigens are "expressed" by all cells but do not provoke a strong immune response; in some cases, they may provoke no response at all. Class II antigens provoke a strong immune response but they are not displayed by all cells. The most important cells that display class II antigens are those associated with the immune system and the dendritic cells, such as the skin's Langerhans cells, which sensitize the body to substances entering through the skin. Significantly, fibroblasts do not normally display class II antigens.

Thus, the fibroblasts that form Bell's dermal equivalent provoke only a limited immune response. Bell has thus found that he can graft his skin equivalent across major immunological barriers with only transient inflammation. Skin equivalent from one strain of rat, for example, can be grafted onto a second strain without rejection. Some barriers do exist, though: rats reject grafts prepared from the cells of humans and guinea pigs.

In light of these experiments, Bell predicts that it should be possible to treat human burn victims with skin equivalent prepared with human fibroblasts and epidermal cells collected from volunteer donors, infant foreskins collected during circumcisions, and skin collected during surgical procedures. Skin equivalent could be prepared in advance and frozen until needed. (Several companies have expressed interest in using Bell's technique and some have provided research support.) Calfskin and pigskin seem to be the most promising sources of collagen. Bell and Seymour Rosen of Harvard Medical School have received permission from their institutions to begin clinical trials with the material, and Rosen expects to begin treating severely burned patients in the near future.

Making Successful Grafts

The third approach to providing artificial skin is the oldest and, potentially, the most controversial. As long ago as 1948, British immunologist Sir Peter Medawar observed that it was possible to grow sheets of epidermal cells in culture. He and later workers predicted that it should be possible to use these for skin grafts. Those first experiments were disappointing, however: the cultured cells did not proliferate and the epidermis did not expand greatly. Grafts of the epidermal cells, moreover, did not inhibit wound contraction.

More recent work seems much more promising on all counts. Howard Green of Harvard Medical School, for example, has devised a technique that makes it possible, "beginning with a skin sample as small as one square centimeter [about one-sixth of a square inch], to expand the amount of cultured epidermal cells to an area comparable to the body's entire surface."

Green cultivates epidermal cells with fetal 3T3 cells, a form of fibroblast, that have been lethally irradiated so that they cannot proliferate. The 3T3 cells provide a support for the epidermis and keep the fibroblasts in the biopsy specimen from proliferating in cancer-like fashion. The culture must also contain epidermal growth factor (a chain of amino

Engineering Artificial Skin

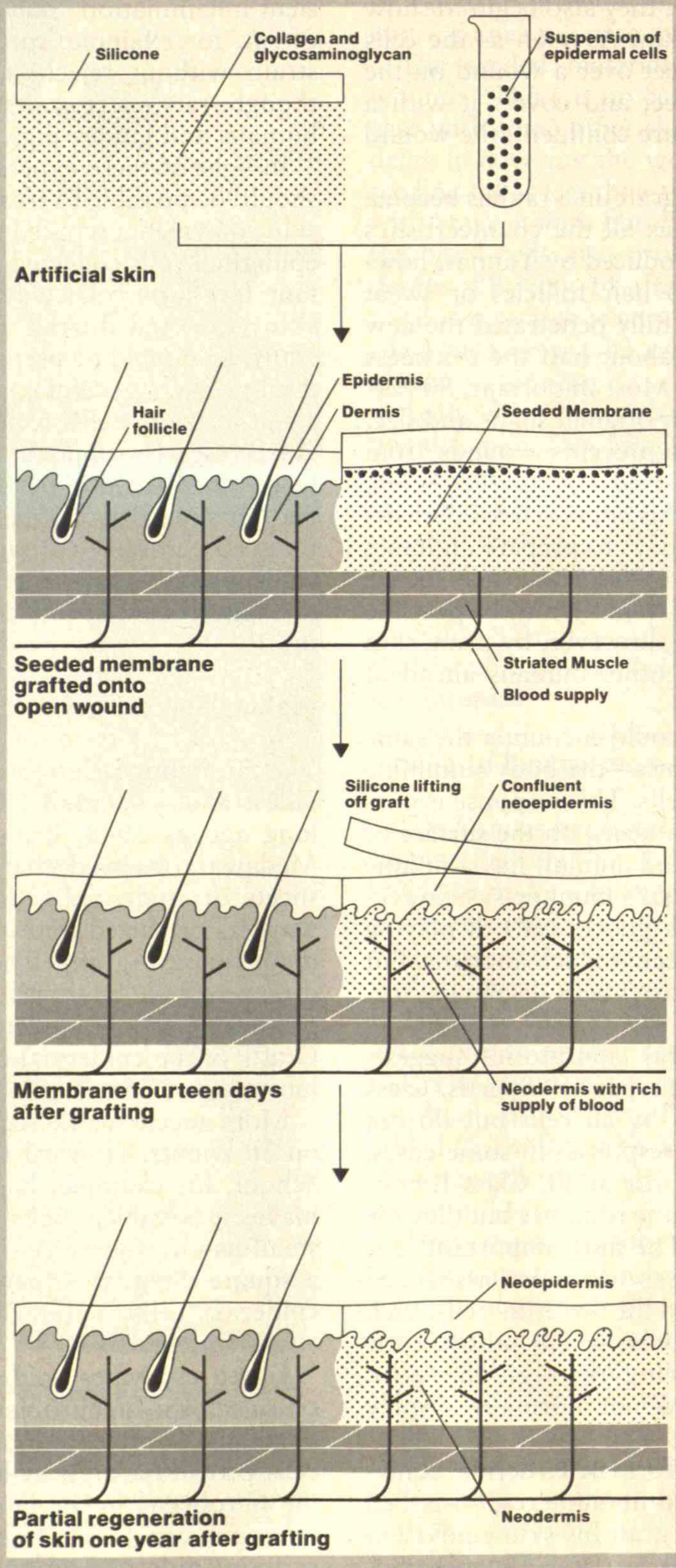
BY DENNIS P. ORGILL AND EUGENE M. SKRABUT

SKIN is a complex organism that, among other things, adheres strongly to the flesh beneath it, moves in response to a wide range of mechanical forces, acts as a membrane for selective passage of different fluids, and sensitizes the body to invasion of toxic compounds. It's not surprising, then, that designing a replacement for the skin of severely burned patients demands more than the skills of applied biochemistry. In our work on Stage 2 skin at M.I.T. *(see page 51)*, we rely heavily on a mix of biological and physical sciences and engineering.

For example, if a graft based on Stage 2 skin is much stiffer than normal skin, it will separate from the underlying wound. The reason is a mismatch in the "moduli of elasticity"—the characteristics that indicate how far different substances stretch in response to a pulling force.

Designers must bear other mechanical characteristics in mind as they select materials for grafts. The membrane must be limp enough, for example, to drape comfortably over the body's wide range of curved surfaces—from the inside of the armpit to the outside of the elbow. One of the most important measures of draping behavior is "flexural rigidity." This is the product of the modulus of elasticity and the moment of inertia, the latter indicating the tendency of a chunk of material to move in response to a force. Designers look for a biomaterial with a modulus of elasticity close to that of normal skin and then adjust the material's thickness (which determines its moment of inertia) to achieve the appropriate flexibility.

Physics enters the design via surface energy, which determines the tendency of two different materials to adhere to each other. The surface energy of the interface between the graft and the wound bed must be lower than that of the interface between air and the wound bed. That enables the graft to displace air from the surface of the wound. Without this good contact, pockets of air will build up in the interface and predispose the wound to infection. Maintaining close contact is particularly challenging in the case of concave surfaces, such as the back of the knee.



Artificial skin must also simulate the real thing in its resistance to moisture. If too much water can escape from the inside, the membrane will dry out, curl up, and separate from the wound. But if the skin allows too little water to pass through, fluid will build up beneath it. We chose silicone to form the skin after experiments showed that its permeability to water closely resembles that of normal skin.

Artificial skin must be practical for everyday use. It must, for example, have a shelf life of about one month and be packaged for easy use. It must be strong enough to survive handling and suturing during surgery, and it should adhere to the wound tightly enough so that it does not fall off when the patient moves.

Artificial skin must also be nontoxic and noninflammatory, and should not induce a significant immune response in its recipients. Our group has added another requirement: Stage 2 skin should be biodegradable—dwindling away at roughly the same rate as new tissue forms in the wound. □

DENNIS P. ORGILL and EUGENE M. SKRABUT are research asociates in M.I.T.'s Department of Mechanical Engineering.

DIAGRAM: OMNIGRAPHICS

The Selby boys' underarms were just about the only parts of their bodies not severely burned.

acids that increases the rate at which the colony expands) and an agent to increase the metabolic activity of the cells. Surprisingly, the most effective agent is cholera toxin.

Cultures inoculated with 10,000 epidermal cells (in a 50-millimeter culture dish) become confluent in 14 to 17 days. Green has found that the cultured cells behave remarkably like cells in intact skin: the tissue divides into layers reminiscent of the epidermis, and keratin is formed. There is no evidence to suggest any loss of growth control—that is malignancy—in the cultured cells.

For transplantation, scientists use an enzyme to detach the cultured epidermal sheet from its dish. Once freed, the highly elastic sheet shrinks to about 40 or 50 percent of its original area. It is then placed directly on the wound, and held in place by gauze impregnated with Vaseline. Experiments have shown that donor rats accept a graft based on their own skin; a dermal layer appears to regenerate beneath the epidermis, and wound contraction is minimal. The rats reject allografts produced using this technique, however.

The final appearance of the graft is much the same as that produced by the other techniques, yielding what Green terms "a serviceable epidermis." Green and Dr. Nicholas E. O'Connor of Brigham and Women's Hospital in Boston reported in 1981 that small epidermal grafts had been used successfully on two burn victims. O'Connor has since performed somewhat larger grafts on five more patients and plans to extend the studies to larger numbers of burn victims.

Green's technique really proved its worth in 1983, when a team from Massachusetts General Hospital used it to replace more than half the skin area of two young brothers. Glen Selby, 6, and Frank, 7, from Casper, Wyo., suffered burns over 97 percent of their bodies when solvent that they were using to remove paint from their skin caught fire. Since more than 80 percent of their skin was completely destroyed, said MGH surgeon Dr. Gregory Gallico, the brothers had "no other hope for survival" beyond the growth of epidermal cells.

As its source of epidermal skin, the medical team used patches from the boys' underarms, which were just about the only parts of their bodies not severely burned. Within several weeks, Green's culture produced extensive areas of fresh skin. To minimize the stress of surgery, however, the team grafted it onto one large burn area—such as the abdomen or a thigh—at a time. The two brothers have now developed thin, smooth, shiny skin that serves its purpose well. Although the boys face further plastic surgery, physical therapy, and counseling, doctors believe that they are well on the way to recovery from burns as extensive as any ever survived by human beings.

Magdalena Eisinger of Memorial Sloan-Kettering Cancer Center in New York City is also growing cultured epidermal cells. She does not use the 3T3 cells but appears to get much the same effect by using an acidic culture medium. She peels the sheets of epidermal cells from the walls of the flask rather than removing them with an enzyme, and supports them on a sheet of collagen instead of gauze.

On the whole, however, Eisinger's results have been remarkably similar to Green's. She has performed autografts to cover surgically prepared wounds on about 25 pigs and a few dogs and reports "very beautiful healing." Martin Carter of Rockefeller Unversity will conduct trials on humans in the near future. Meanwhile, John Hefton, who has moved from Eisinger's laboratory to New York Hospital, has successfully performed grafts of this type on a small number of patients.

There are two key problems with this approach. One that may be solved soon is credibility. Many investigators, perhaps unduly swayed by the poor early results obtained by Medawar and others, contend that cultured epithelial cells are simply not a good source of grafts and that they do not inhibit wound contraction enough. This attitude will presumably be overcome as Green, Eisinger, and Hefton continue to report success.

A more significant problem is the amount of time required to grow enough graft material. Because there is no evidence that allografts will work in humans, and some evidence to the contrary in animals, it seems likely that it will be necessary to use autografts. The difficulty then becomes figuring out a way to cover the wound while waiting for the graft to grow. One possibility, notes Green, would be to use a temporary allograft. Although the allograft would ultimately be rejected, it would buy the surgeon some time during which the new skin could be prepared.

For the time being, the use of any of the artificial skins will be restricted to burn victims in the greatest danger of dying. The need to prove that the technique is effective and the shortage of materials make

Artificial blood vessels could be especially useful in bypass operations.

this approach necessary. But Yannas notes that surgeons may eventually extend the technique to less severely injured victims of second-degree burns. Synthetic skin might even be used to replace scars on patients who have been previously injured. Such an application is far in the future, however, and will require both more research on animals and a new set of clinical trials.

From New Skin to Fresh Organs

The techniques for producing artificial skin might also lead to methods for making other organs. Yannas has speculated, for example, about using templates like those prepared for skin to induce other body parts to regenerate. Bell, in fact, has already produced an artificial thyroid gland.

The key to this work is the possibility that undesirable cells displaying class II antigens can be separated from desirable cells displaying only class I antigens by cell culturing. This approach was very nearly discredited in 1974 when William T. Summerlin, then at the Memorial Sloan-Kettering Research Center in New York, was accused of fabricating some research results and misinterpreting others. Summerlin had claimed that culturing skin, corneas, and certain other tissues for one to two weeks somehow changed the tissues, enabling them to be transplanted across immunological barriers. But when other investigators could not reproduce his results, the technique fell into disrepute.

A few investigators, particularly Kevin J. Lafferty of the University of Colorado School of Medicine and Paul E. Lacy of the Washington University School of Medicine, persisted and were eventually rewarded with success. Lafferty showed that thyroid glands could be transplanted across immunological barriers in mice if the glands were first cultured for 12 days under precisely controlled conditions. Lacy had similar results with islets of Langerhans, the clusters of pancreatic cells that produce insulin. Subsequent investigators have reported similar findings. Both Lafferty and Lacy speculated that circulating cells with class II antigens either died or were separated out during the culturing process, sharply decreasing the risk of an immune reaction.

Bell has used a culturing technique to produce what he calls a "thyroid gland equivalent." He prepares the tissue as he does the skin equivalent, but instead of epidermal cells, he uses thyroid cells from a strain maintained by Heyden Coon of the National Institutes of Health. The thin tissue thus formed is implanted under the skin, where it is quickly penetrated by blood vessels. A later tissue sample shows that the thyroid cells have gathered into follicles that produce the hormone thyroglobulin, which is important in weight control. This occurs only if the recipient's own thyroid has been removed, and there is no evidence that the thyroid cells proliferate.

There is also no direct evidence that the fresh follicles actually release thyroglobulin. Nonetheless, rats whose thyroid gland have been removed gain weight if the thyroid equivalent is implanted, suggesting that the hormone has passed into the blood streams.

Bell is currently studying other applications of the technique. His group is trying to make a pancreas equivalent using cultured beta-cells (the cells that produce insulin) rather than islets of Langerhans; such a tissue could be used to treat diabetics.

Bell and Crispin B. Weinberg have also developed a method to make artificial blood vessels, which might be particularly useful for bypass operations. A synthetic blood vessel is produced by covering a tubular mold with a mixture of collagen and smooth muscle cells from blood vessels. The cells cause the collagen to compress into a tight layer. This layer is encased in a Dacron mesh for strength and coated with fibroblasts. Finally, the vessel is removed from the mold, and endothelial cells—the type that inhabit the lining of blood vessels—are cultured on the interior. The finished product is flexible but strong enough to withstand twice the pressure likely to be encountered in the vascular system. The synthetic vessel even secretes two hormones produced by normal blood vessels. Bell and Weinberg are now beginning studies with the synthetic vessels in animals.

More complex organs are farther off in the future, but both Yannas and Bell contend that they are not impossible. For the present, however, researchers will be satisfied simply with more successes like those of Mark Walsh and the young Selby brothers.

THOMAS H. MAUGH II is a member of the Research News staff at Science *magazine. He holds undergraduate degrees in both humanities and chemistry (M.I.T.) and a Ph.D. in chemistry (University of California at Santa Barbara).*

Continued from page 14

whether DOE should make a "preliminary determination" of suitability before it actually does geologic tests at the potential sites. The states wanted the tests done first; the DOE disagreed. Benard Rusche, DOE's new director of civilian radioactive waste management, resolved the dispute last June with a timely compromise: he agreed to conduct tests first.

But underlying problems remain. The states are still deeply suspicious of the DOE site selection process, and they have little faith in the hearings on safety and environmental effects to be held before the Nuclear Regulatory Commission (NRC) grants a license to build a facility. State officials reason that if things get that far, the site will already have been approved by the DOE, the president, and Congress. That's a pretty big steamroller to stop.

No Technical Unknowns

Given the current state of affairs, the alternative of building a semipermanent repository would make good sense. Such a facility offers two important advantages: technical simplicity, and the fact that any mistakes in packaging the waste could be easily corrected. There are important safety advantages in a facility that allows inspection and maintenance of the waste, whether it is above or below ground. And since there are essentially no technical unknowns to argue about, building such a facility should be simple and inexpensive.

A variety of schemes have been proposed for semipermanent storage. One widely accepted approach would be to build structurally enclosed concrete cavities near the surface of the ground, fill them with water, and put the spent fuel in the water. After some years, water cooling would be unnecessary, and the spent fuel could be placed in concrete canisters for extended storage. Maintenance people would be able to spot and fix any flaws and repackage the waste if necessary.

Spent fuel is now being stored at nuclear reactor sites under similar conditions. But moving the waste off the reactor sites and into sound containers in central facilities would be an improvement. Not only could the waste then be managed by specially trained staffs, but it would cease to be a distraction for the utilities that operate reactors. They have enough to worry about.

Surface repositories have another advantage: their effectiveness does not depend on special geology, so the constraints on their siting are far fewer. Officials would not, for example, have to choose a site next to a national park in Utah (a candidate for a deep repository) simply because it offered a nice salt formation.

Indeed, the law requires DOE to submit a proposal to Congress by June 1985 on establishing such a semipermanent facility under the rubric "monitored retrievable storage." Although DOE has until now downplayed the MRS option (technical bureaucracies naturally shy away from low-cost solutions), there are signs that the department is changing its mind and will support MRS as an integral part of its overall program.

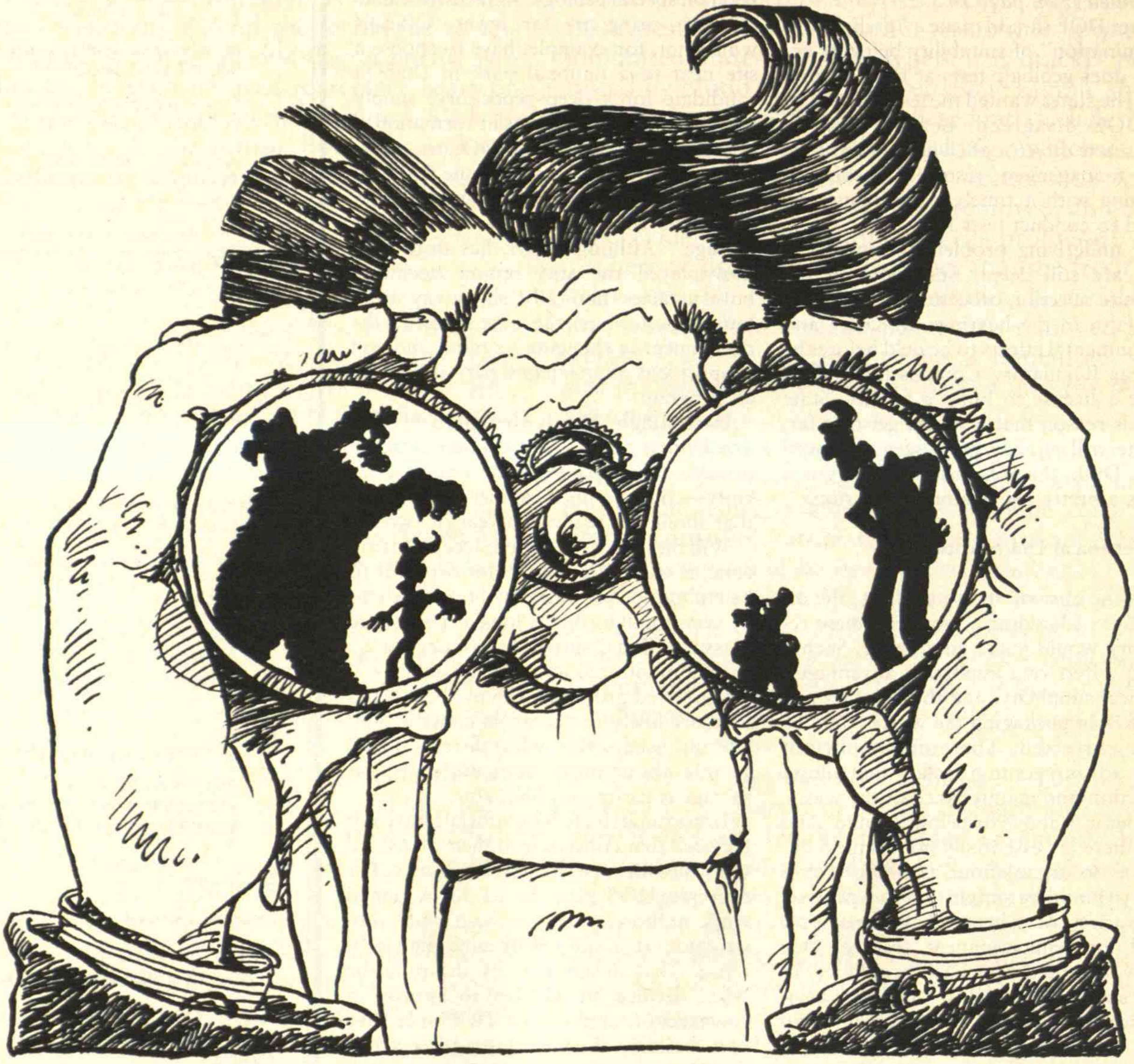
Interestingly, this is the approach that Sweden has taken. That country is in the process of completing a near-surface facility—concrete-lined cavities in granite—that should be ready in a year or two.

Will the American people accept this avenue as well? We should not expect it to be embraced; no waste facility is likely to be very popular. But as long as people are reassured that a surface repository can be closely monitored and that mistakes will be corrected promptly, I think they would be more likely to accept its construction. I firmly believe that what disturbs many people about permanent underground storage is its irrevocable nature.

Unfortunately, federal officials have not factored that concern into their plans and schedules for a permanent repository. For example, DOE plans to ask for a limited work authorization so it can start construction at a site before obtaining a license. That means that by the time the NRC decides on whether to approve a construction application, DOE will have been building the facility for three years. On paper, this is a way of allowing DOE to meet the nuclear waste act's 1998 deadline. In practice, it is a recipe for trouble. It means that sensitive issues such as geologic uncertainties will be reviewed under the pressure of construction commitments and investments. This is precisely the kind of thing that scares the states.

A principal argument against near-surface storage has been that such a program would slow down efforts to establish a permanent geologic repository. That may happen, but we should be more worried about putting all our eggs into one basket and then failing to build any storage facility. It makes sense to start with something we already know how to do. □

The New War and Peace: Coming to Terms with the Russian Bear



In 1957 a White House group concerned with U.S. nuclear vulnerability visited Gen. Curtis LeMay at the U.S. Air Force's Strategic Air Command. At the time, President Eisenhower maintained that the United States had an effective deterrent: if attacked by the Soviet Union, this country could get enough bombers off the ground in an hour or two to deliver a devastating retaliation. But Jerome Wiesner, a member of the group who is now Institute Professor at M.I.T., recalls the observers found a problem: "We don't think you can get those planes off the ground in 24 hours," they told LeMay.

"You're right," LeMay replied. "But our intelligence is very good. We'll know a week before the Russians are going to do anything, and we'll knock the . . . out of them." This general had unilaterally settled on a first-strike policy, Wiesner maintains. "Eisenhower did not know it, yet it must have been obvious to Soviet intelligence."

Troubling contradictions of this kind in U.S. strategic policies came to light last fall in a panel discussion sponsored by M.I.T.'s Technology and Culture Seminar. Wiesner and several other faculty members discussed nuclear arms with Paul Warnke, chief U.S. negotiator of the SALT II treaty under former President Carter. Warnke was representing the Mondale campaign; despite repeated requests, the Reagan campaign had declined to send someone to the discussion.

A Troubled Past

No one in the panel blamed the Reagan administration alone for the meager successes in limiting nuclear weapons. As Warnke put it, "Nobody can look back with much applause at the record of arms control."

An important reason for that failure, the panelists agreed, is the contradictory nature of U.S. strategic policies. On the one hand, all presidents since Eisenhower have held that nuclear weapons are intended to deter the Soviet Union from using its arsenal, not to strike first. In his state-of-the-union address last year, President Reagan maintained that the only value of nuclear weapons is to ensure they won't be used.

However, theory has not squared with practice. Carl Kaysen, director of the Science, Technology, and Society Program at M.I.T. and a member of the White House staff in the Kennedy and Johnson administrations, pointed out that military strategists inevitably target the opponent's weapons. This seems preferable to targeting civilian centers. But, Kaysen explained, then the strategists say, "Now that we've targeted these weapons, we have to be able to hit them. Let's get more and more accurate missiles." Accurate missiles, especially those carrying multiple warheads, are primarily useful for a first strike.

The most recent example is the MX. The 10 bombs on each MX can be dropped precisely on Soviet missiles—if they are still in their silos. If the Russians ever launched their missiles, the MX would provide excellent retaliatory capability against a lot of holes in the ground. Of course, the MX program was initiated by the Carter administration. As Wiesner told Warnke, "Whether you guys knew it or not, you were buying a first-strike capability." Warnke agreed: "I told the president that three times."

Unfortunately, strategies for fighting nuclear war have gained ground under the current administration, Warnke said. Secretary of Defense Caspar Weinberger said in the annual report to Congress in 1982 that the United States needed the ability to "terminate" a nuclear war on "favorable" terms. "If that's the purpose of our nuclear arsenal, let's forget about arms control," Warnke said. "We will not be able to maintain that capability with the consent of the Soviet Union."

The Giant Pygmy

A further contradiction in U.S. strategic policy is reflected in Reagan's two incompatible views of the Soviet Union, Warnke maintained. "One is that the Russians are 10 feet tall. They're directed toward the conquest of the world by force and violence. The second is that they're pygmies. All we have to do is ratchet up the competition and they'll collapse."

This mentality leads to the "arms-race theory of arms control," Warnke said. "A member of my delegation to the SALT II talks maintained that we really needed an arms race. The Russians would recognize that they couldn't keep up, that they did not have the resources or technology, and they'd cave in. Regrettably, that person, Gen. Edward Rowny, is now the chief strategic-arms negotiator.

"In accordance with this theory, the president predicted that as the United States deployed Pershing II and cruise missiles in Europe, the Soviet Union would begin to move toward our proposals to reduce these intermediate-range weapons. The Russians said they would walk out of the talks. They walked out.

"In the START talks on long-range nuclear weapons, the United States asked the Soviet Union to dismantle most of its land-based missile force, which holds 85 percent of all its warheads. Alexander Haig, the former secretary of state under Reagan and not a notorious Soviet sympathizer, called this U.S. position 'absurd' and 'nonnegotiable.'

"Either both sides will reduce their weapons or both will build them up. Those are the only alternatives," Warnke maintained.

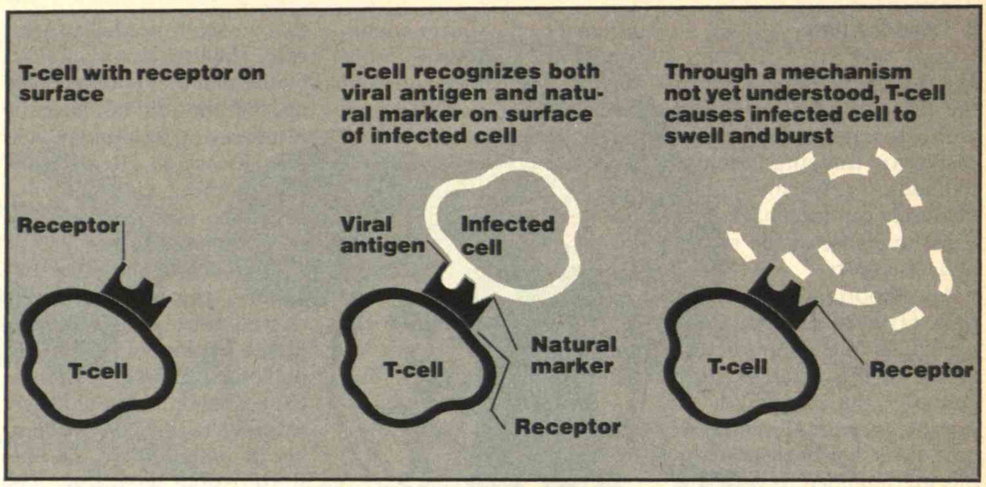
He proposed that the Russians are "about five feet ten. A decent height: it's my height." He did not mean to certify them trustworthy. "I've practiced law in Washington for 36 years. I don't trust anybody." But treaties can be verified. Although in the vice-presidential debates George Bush maintained that SALT II was unverifiable, when it was signed, both the joint chiefs of staff and the Central Intelligence Agency attested to the contrary. "Vice-President Bush was at one time the director of the Central Intelligence Agency," observed Warnke. "For some reason these facts escape his mind."

If the United States is prepared to forego a search for nuclear superiority and to accept the idea that nuclear weapons exist solely for deterrence, Warnke maintained, this country can negotiate arms reductions. Of the two adversaries, the Russians are more afraid of war: they are more vulnerable. "As a friend says, the Soviet Union is the only country in the world that's surrounded by hostile communist countries"—China and the restive socialist states of Europe.

Given the political will, the technical means to reduce the chance of war should not be hard to find. Wiesner proposed a ban on testing of missiles and warheads, for example. "After a time no government officials would be left who had seen a bomb or rocket fired, so they wouldn't have much confidence that these weapons would work. That is just why the joint chiefs insist that there be testing." However, an unreliable system has advantages. "It's not one that you're very willing to use for a first strike. But it would work as a deterrent. If you fired a hundred of these missiles, nobody would want to bet that a few, or a dozen, or half of them wouldn't go off."—*Jonathan Schlefer* □

ILLUSTRATIONS: JON McINTOSH

Unlocking the Secrets of Immunity



T-cells form the first line of defense against disease. They seek out and destroy cells infected with viruses, fungi, and bacteria. A receptor on each T-cell distinguishes an infected cell from a normal one. But before a T-cell can destroy the infected cell, its receptor must "recognize" both the antigen, which signals the presence of a virus, and the natural marker, which is specific to the cell. People often succumb to disease when their T-cell receptors fail to recognize both markers.

Molecular biologists have found a crucial clue to how we defend ourselves against disease. Three groups of scientists at M.I.T., Stanford, and the University of Toronto recently decoded the gene for the "T-cell receptor." This molecule sits on the surface of cells that play an essential role in the immune system and enables them to distinguish between normal and infected cells—between "self" and "nonself."

"Now that we know its genetic structure, we can clone large quantities of this receptor and observe its behavior in cell cultures," says Herman Eisen, professor of biology at M.I.T. and one of the investigators involved in the research. Such observations should eventually solve "a fundamental problem in biology": how the human immune system can recognize and attack certain cells infected with disease while leaving others intact.

Understanding that process could help physicians prevent patients' immune systems from rejecting kidney or liver transplants. It would also explain why some people succumb to disease while others, similarly exposed, remain healthy. And it may help researchers understand why in cancer the immune system sometimes fails to recognize cancerous cells as foreign.

Hidden Viruses

The human body manufactures millions of T-cells, which reside in the lymph system and circulate through the bloodstream. Different forms of T-cells are responsible for seeking out and destroying viral, fungal, and even some bacterial infections. Their comrades-in-defense, B-cells, target other forms of bacteria. The body produces enough of both these types of immune cells to protect itself against virtually any foreign agent that might invade the body. Yet people still get sick, often because T-cells are unable to recognize the invading substance.

Suppose the invader is a virus, an infectious packet of genetic information that replicates inside living cells and eventually kills them. Each invaded cell is marked by an antigen, which signals the presence of that virus. However, nature has made it impossible for an individual's T-cells to recognize an antigen unless they also recognize another natural marker on the surface of the cell. Not only does each type of cell have a marker specific to it, but every human being has a different set of markers. Without these natural markers, the T-cell would never be able to distinguish a cell from a free-floating molecule.

In the defense against disease, the natural markers generally bond to the viral antigens. People often succumb to a particular virus because their cells don't have markers that can bond to the antigen of that virus. As a result, the T-cells are unable to locate the invading virus, and people with this deficiency have no natural defense against that viral disease.

Theirs is a special kind of sacrifice. In a sense, these people are victims of evolution's drive to preserve the human race through diversity.

"If we all had the same set of natural markers, the entire human race could be wiped out," says Eisen. All it would take is one virus with an antigen that didn't bond to any natural markers.

A Lock with Two Keys?

Now that scientists can clone T-cell receptors, they can begin to observe how these receptors recognize linked pairs of antigens and markers on the surface of infected cells and why certain receptors can "locate" only certain pairs. But the researchers' task is formidable. The body manufactures millions of receptors, each slightly different in structure and able to recognize a slightly different pair of marker and virus.

Furthermore, Eisen cautions, there may be a second receptor on the surface of T-cells that has so far escaped detection. "It could be that one T-cell receptor recognizes the antigen marker of a foreign substance, and one recognizes the natural marker of the cell," Eisen says. The effect would be that of a "lock with two keys," which, of course, would be much more difficult to open.—*Alison B. Bass* □

DIAGRAM: OMNIGRAPHICS

End of the End of the Train

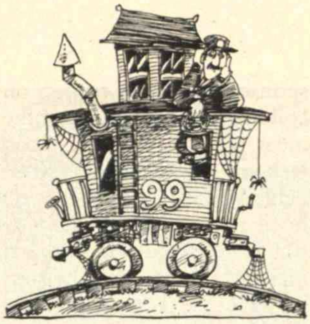
Add another item to the list of favorite American images that are disappearing with the advance of electronics: the railroad caboose, that stove-heated shed on wheels from which train crews have long surveyed cars and countryside.

Computers have already taken over the task, once assigned to the caboose's occupants, of maintaining lists of the train's cars. Also, more and more trains move as units among major yards. There is therefore less and less need for caboose crews to handle uncoupling and switching at the end of the train.

Another crucial function of the caboose's occupants has been to make sure that the air pressure is maintained in the brake system at the end of the train. Now this job, too, is being assumed by 30-pound black boxes that simply hang from the last car. Several manufacturers are competing to provide U.S. railroads with detectors that automatically measure brake pressure and transmit it by radio to display devices in the engine cab. The train's required rear-end red warning lights sprout from the same boxes.

In early 1984 Conrail began removing cabooses from freight trains—first from short trains on local runs and then, starting May 1, from through trains. By August almost 50 Conrail mainline freight trains a day were operating with black boxes instead of cabooses.

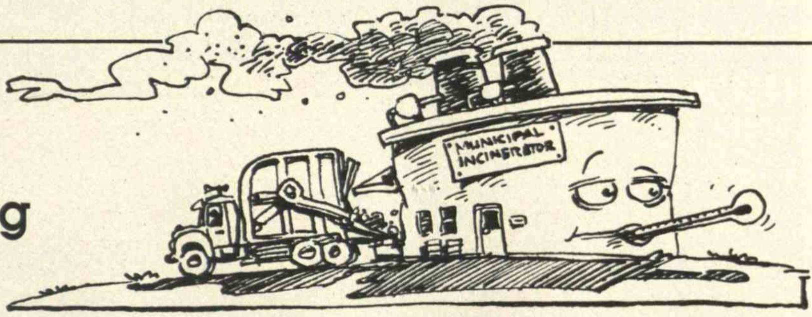
Though railroad buffs may be disappointed, railroad managements are pleased. A caboose costs about $80,000, according to *Modern Railroads* magazine, and each one requires a $3,000 to $5,000 overhaul at least once every 10 years. Furthermore, constant monitoring of air pressure by electronics gives engineers better information than they've had from radio dispatchers in cabooses.



But a few cabooses will stay. When a train is backed up, someone has to be at the end to watch where it is going. Union rules allow a crew member to stand guard on an exposed ladder on the last car for short distances. When a train is backed up for more than a mile—and such maneuvers are not uncommon as long, modern trains are assembled—a caboose will still be necessary as the rear guard's outpost.

—John Mattill □

Dioxin from Burning Trash



Dioxin, the notorious contaminant in herbicides such as Agent Orange, has now been found in an unlikely source: the emissions of incinerators that burn ordinary trash.

These emissions contain only traces of dioxin, and no one is certain that this chemical has any chronic effects on humans, even at greater doses. However, dioxin does cause reproductive problems, cancer, and death when given to animals in very small amounts. Furthermore, municipalities across the country are turning to incineration as their landfills reach capacity or close because of environmental problems. According to a report from the U.S. Conference of Mayors, 98 "resource recovery plants"—incinerators that put the heat they generate to use—are already operating, under construction, or about to be built. Another 90 such facilities are in earlier stages of planning. A report by an advisory committee to Environment Canada, the environmental protection department of the Canadian government, estimates that improperly operated industrial and municipal incinerators are the largest source of "chlorinated dioxins" emitted into the environment. This group of chemicals includes the substance commonly referred to simply as dioxin.

Incinerators can also emit other toxic substances such as dibenzofurans. However, these aren't considered as potentially dangerous to humans as dioxin.

Just how dioxin is formed during combustion is "the million-dollar question," says William Schaub, a scientist at the National Bureau of Standards. Some researchers have hypothesized that when plastics in trash burn, they may form molecules that in turn combine to produce dioxin. However, this can't be the only way dioxin is produced, since it has been detected in automobile mufflers and even wood-stove pipes, where there are no plastics. Michael Cook, coordinator of the EPA's Dioxin Management Task Force, suggests that whenever burning temperatures are too low, oxygen is inadequate, or combustion conditions are otherwise poor, molecules in many kinds of organic matter are only partially broken down. These products may combine to form dioxin and the other toxic substances found in emissions.

Engineers believe they can control dioxin emissions by improving combustion. The American Society of Mechanical Engineers (ASME) and the New York State Energy Research and Development Authority are planning to

sponsor a research project on combustion conditions at the incinerator operated by Vicon Recovery Systems in Pittsfield, Mass. The project is on hold pending approval of funds from the U.S. Department of Energy, the Environmental Protection Agency (EPA), and several state governments. If the tests go forward, engineers will vary the burning temperature, amount of air allowed in the combustion chamber, presence of plastics in the trash, and other factors. The researchers hope that the results will tell more about how to monitor and reduce dioxin and dibenzofuran emissions from all municipal incinerators.

Even if incinerator managers apply the lessons from these tests, no one knows whether all dioxin emissions can be eliminated. Since dioxin tends to become attached to ash going up the chimney, emissions-control devices that filter out solids could provide a final check, says Schaub.

Japan, West Germany, and Switzerland are already regulating municipal-waste incineration. In addition to limiting the emissions of general air pollutants such as sulfur oxides, these regulations set standards for substances such as hydrochloric acid and hydrocarbons that tend to be produced along with dioxin. (Dioxin emissions themselves are difficult to measure.)

In the United States, legislation was passed last fall to reduce dioxin emissions. An amendment to the Resource Conservation and Recovery Act requires the EPA to assess the risks of dioxin from resource recovery plants within 18 months, and to set operating procedures to control the emissions.—*Sharon Moran* □

Squatter Settlements: If You Can't Beat 'Em, Join 'Em

On a sweltering Saturday in Managua, Nicaragua, amid a seeming junkyard of lumber, cinder blocks, and iron pipe, you can see people building. You might wonder why they are working so hard. All their industry seems to be producing is a lot of shacks—another Latin American squatter settlement.

However, on closer inspection you discover that, unlike the typical squatter settlement, this one has streets, running water, and sewers already built in. Furthermore, the workers own title to the land. "This settlement is planned to be upgraded," says Roberto Chavez, Nicaragua's director of urban planning. In the eyes of the builders, the shacks going up are the modest beginnings of dream houses.

The Nicaraguan government says that its "sites-and-services" programs, providing plots for people to build on and services such as roads and water, are producing some 10,000 housing units a year. More important than the number is the idea of a government's institutionalizing—co-opting, if you will—the customary squatter settlements. Nicaragua has probably taken this approach the furthest, but that country is far from alone in espousing it. For example, the World Bank, where Chavez worked on Latin American housing projects for eight years before going to Nicaragua, is promoting some of the same ideas.

In the 1960s governments in developing nations from Indonesia to Peru began to face

PHOTOS: PEDRO BRAN, RAY WITLIN (WORLD BANK)

the fact that mass migration of peasants into cities is neither temporary nor, for the foreseeable future, reversible. Today the problem looms larger than ever: according to the World Bank, the population of African cities will increase fourfold by the year 2000.

By the mid-sixties international lending institutions such as the World Bank began lending money to these governments to build housing projects. However, there were problems. One was bureaucracy, as illustrated by a project carried out between 1977 and 1979 to build "minimal housing" in Honduras' second largest city, San Pedro Sulla. According to Luis Sierra, a Honduran urban planner who studied the program, the government established eight requirements for anyone who wanted to be accepted, including proof of being a citizen and having paid taxes. Families who had migrated from villages where no records were kept were automatically rendered ineligible. Many who did qualify managed to do so only after Peace Corps volunteers had led them through the maze of government bureaucracy.

But the worst problem in building housing, at least in Chavez's experience at the World Bank, has been financial. Like all bank loans, those provided by lending institutions to governments for housing are intended to be recouped. To secure the necessary income, governments issue long-term leases or mortgages to occupants of the projects.

These financial arrangements pose a nearly impossi-

Rather than building entire housing projects, some Third World governments are putting in running water, roads, and sewers—in effect providing "sites and services." Owners make their own homes, much as in traditional squatter settlements. Left: A sites-and-services project in Managua, Nicaragua. Above: A new drainage ditch under construction at a World Bank project in Jakarta, Indonesia.

ble choice. "You can simply build housing for those who can pay for it: the middle class," says Chavez. "Or you can lower your standards so poorer people can pay." In extreme cases such as in Haiti, Chavez says the World Bank's efforts to lower costs—and therefore quality—turned the program into one of virtual slum replication. And even that strategy hasn't worked financially. According to Anthony Churchill, the bank's director of urban development, of the 62 housing projects the bank has launched in the past 15 years, none has completely recouped its cost.

Don't Build Houses

In many ways, squatter settlements may be a better model for Third World housing than planned communities directed from above. For example, in Honduras, says Sierra, "the government went to all the expense to build those little houses, but there were still families who didn't qualify. So a funny thing happened. The people set up a new settlement—what we call an *invaçion*—just across the street from the government project." The residents lobbied the government to provide their settlement with services such as water, and they ended up in effect with a sites-and-services project.

The lending institutions realized that sites and services could often be provided more cheaply than complete housing. And since government-sponsored housing projects tend to be unpopular worldwide, sites-and-services projects have provided a welcome alternative. Several such communities have been built in countries such as Zambia, Indonesia, and Botswana. For example, in Botswana, rural migrants were pouring into Francistown, a new mining community. Working with the World Bank, the government created 800 sites-and-services plots, thereby establishing a planned community but letting individual families build and improve their homes as their incomes rose.

Sites-and-services projects have reached a broader segment of the population than the World Bank's houses, and the residents have lower mortgage payments—some as little as $50 a month. However, even that amount is substantial in some developing countries, and many projects require higher payments. Mortgages have generally been too high for the local economy, according to a 1983 U.N. position paper, and there is also a sociological problem. Used to settling on free land, squatters simply haven't adopted the middle-class mentality of making mortgage payments.

Thus, sites-and-services projects for migrants to Third World cities must imitate squatter settlements in one final way, Chavez concludes: the sites must be free. Most governments have not been able to provide free plots. Even governments that have tried—those in Mali and Tanzania, for example—have often found that the potential revenues from urban land are so great that they cannot afford to use it for housing. The Sandinistas in Nicaragua have been able to provide free sites because the policies of the socialist government favor land reform, and also because the 1979 revolution freed the vast holdings of the former ruling family, the Somozas. "The Sandinistas can hand out just about all the free land they want," says Lisa Peattie, professor of urban studies at M.I.T.

The Sandinistas have also broken with usual housing practices in another way. Squatters are generally considered eyesores, and governments relegate housing projects to the outskirts of cities. This means that bringing services out from the urban core to these areas is expensive. And the distant location of settlements weakens their financial viability: residents have to commute as much as four hours a day or else lose their jobs. Thanks in part to the empty areas left by a 1972 earthquake, Nicaragua has been able to build sites and services within Managua.

The familiar cycle of squatter eviction, resistance, and resettlement is becoming less and less acceptable to Third World governments with growing urban populations and mounting social problems. Chavez hopes that developing nations will resolve some of these issues during the next 20 years by providing free sites and services along the lines of the Nicaraguan model. The question Third World planners—and their First World sponsors—are asking is whether they can politically afford to follow this model.—*Joel Millman* □

Accidents, Structural Failures, and Laser Future

Preventing Catastrophic Accidents

Normal Accidents: Living with High-Risk Technologies
by Charles Perrow
Basic Books, $21.95

Reviewed by Deborah A. Stone

Do we hear so much about about the risks of new technologies these days because they are inherently riskier than older ones, or simply because we are a wealthier, more advanced society and can afford to worry about such hazards? Sociologist Charles Perrow, writing in *Normal Accidents*, believes that the risk of catastrophe today is objectively higher. But he reasons that the hazards are greater not so much because technologies are more dangerous, but because the complex control systems they require are highly vulnerable to failure.

Many new technologies, to be sure, *are* more dangerous than older ones. Scientists often do not completely understand the processes they use to transform raw materials such as chemicals or DNA. Society also deals with far more deadly toxic and explosive substances than ever before, and we try to accomplish tasks in more hostile environments, such as in space and under water, and with greater speed and in greater volume. But far more important than the nature of the problems we are trying to solve is the complexity of modern technologies and the social systems necessary to develop and operate them.

Today's technologies are complex in that a single component often serves more than one function—an exchanger might be used to warm a gas tank and also to absorb excess heat from a chemical reactor, for example. Failure of such a "common-mode connection" has multiple consequences. Also, parts in different operating sequences are often in close proximity, so that if one part fails, the disruption may "jump" over into another branch of the system. Perrow cites the example of an oil tanker that hit a submerged wreck, gashing open a spot where its tank adjoined the pump room. Oil seeped into this room, where higher temperatures caused it to flow rapidly into the adjacent engine room, where even higher temperatures and sparks caused an explosion and fire. Modern technological systems also include unintended feedback loops and hidden interactions, so that two or more parts respond together. This "tight coupling" occurs in transportation systems, for instance: if taxi drivers go on strike, demand for bus service surges.

Because designers and operators cannot anticipate all the possible effects in such complex interactive systems, especially those used to transform deadly materials or perform in dangerous environments, failure is inevitable. Thus, we must accept the fact that catastrophic accidents are "normal," Perrow maintains. And we should be skeptical when advocates of these technologies, and the risk assessors they hire, reassure us that major accidents are extremely unlikely.

Power to Choose Risks

Prophets of catastrophe are sometimes easy to dismiss because their rhetoric far outweighs their evidence. Not so with Perrow. He takes the reader on a travelogue of accidents in a variety of settings, including aircraft, airways, and marine craft; dams, earthquakes, mines, and lakes; weapons and space; and recombinant-DNA labs. He also analyzes the chemical industry, a mature, well-run arena where technology is relatively well understood, and where, unlike the nuclear industry, the costs of accidents and shutdowns are not easily passed on to customers. Yet accidents do occur frequently, not "simply" those involving workers exposed to chemicals or communities left with toxic-waste dumps but also large-scale leaks, fires, and explosions. In one rather ordinary segment of the industry—ammonia manufacturing—one-third of plant shutdowns for maintenance stem from major equipment failures, and plants average one fire every 11 months.

Catastrophic accidents may be normal and will probably be commonplace, but because complex technological systems are human constructions, people can also modify or eliminate them. "Ultimately, the issue is not risk, but power; the power to impose risks on the many for the benefit of the few," says Perrow. He criticizes the tendency of risk assessors to dismiss the public's opinions of the risks of various technologies in favor of "objective" analyses. Instead, he maintains that decisions regarding which risks society takes should be based on a democratic process.

Perrow offers a model for making such decisions that tries both to limit the potential for accidents that could kill large numbers of people and to minimize the costs of abandoning high-risk technologies. Toward that end, he divides various technologies into three categories. First are those with either low catastrophic potential or high-cost alternatives, including dams, mining, airways and aircraft, and chemical plants. These can be tolerated but should also be improved. Second are technologies with moderate catastrophic potential and moderate-cost alternatives, such as marine transport and recombinant DNA. These should be strictly regulated. Last are technologies with high catastrophic potential and relatively low-cost alternatives, which should be abandoned and replaced. Not surprisingly, Perrow places nuclear power and nuclear weapons in this group.

Perrow notes that he is certainly not the first to call for an end to reliance on nuclear technologies and for regulation of other hazardous activities. However, his research undermines promises that "better management" and "more operator training" can eliminate catastrophic accidents. In doing so, he challenges us to ponder what could happen to justice, community, liberty, and hope in a society where such events are normal. □

DEBORAH A. STONE is associate professor of political science at M.I.T. and author of The Disabled State *(Temple University Press, 1984), a study of how society treats its disabled citizens.*

ILLUSTRATIONS: KEN GOLDSTROM

Engineering Fact and Fiction

Construction Disasters: Design Failures, Causes, and Prevention
by Steven S. Ross
McGraw-Hill, $37.50

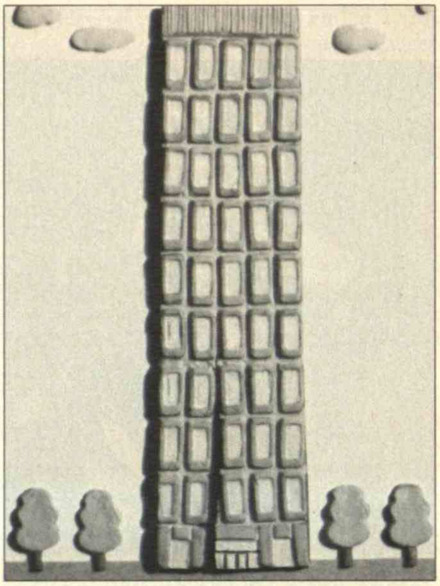
Skyscraper
by Robert Byrne
Atheneum, $14.95

Reviewed by Henry Petroski

For as long as humans have piled stone upon stone there have been structural failures. In earlier times, these colossal mistakes seem to have defined the limits of what could be built. The base of the pyramid at Dahshur rises at a slope of more than 54 degrees, greater than any of its predecessors. However, an avalanche of stone that occurred when the structure was about half completed is believed to have forced the builders to lower their sights and finish the monument at the more conservative angle of 43 degrees. Thus, the Bent Pyramid acquired its characteristic broken profile, and pyramid designers apparently never again attempted to build at so steep an angle. Similarly, medieval cathedral builders apparently strove to construct ever higher and more slender structures until the vaults of Beauvais Cathedral collapsed in 1284. Beauvais was rebuilt with stronger flying buttresses, but most observers concede that Gothic architecture thereafter acquired a timidity that was rarely overcome.

However, in the modern era of theoretical engineering, computerized analysis, and new materials, construction failures do not set the limits of size or daring. If they did, jumbo jets would not have evolved from the first ill-fated commercial jet airliners of 30 years ago, and suspension bridges would not have doubled their spans within 40 years of the spectacular collapse of the Tacoma Narrows Bridge. Today structural failures, while still delineating the boundaries of ignorance, seem also to represent the frontiers of new understanding. For the crash of an airplane and the collapse of a bridge challenge engineers to unravel the reasons why their formulae incorrectly predicted that the structure would be successful.

In *Construction Disasters*, Steven S. Ross categorizes failures drawn from the



pages of the 110-year-old construction weekly *Engineering News-Record.* Ross includes *ENR*'s original reports and followup stories on obscure failures as well as oft-cited ones, and adds stimulating commentary. He points out, for example, that the parties involved in the lawsuits over the glass windows that fell out of the Boston Hancock Tower agreed to keep secret whatever technological lessons might have been gained from that disastrous experience. Unfortunately, the book's design does not highlight where the reports end and Ross's analysis begins, so the reader may inadvertently skip over some interesting commentary.

The Human Element

A more unorthodox method of expounding on engineering design and structural failure, one that is both less precise and more thought provoking, is to construct a novel or a narrative poem around a technical idea with profound implications. Each reader can more easily bring his or her own experiences to bear on the problem, and if the technical ideas are correct, the professional community may sit up and read.

Oliver Wendell Holmes's "The Deacon's Masterpiece," a poem about the absurdity of trying to build a horse-drawn carriage that will not break down, offers so much technical insight that it has been used in the ads of a firm selling engineering instruments. Nevil Shute's 1948 novel *No Highway*, which revolves about a researcher who attempts to convince his superiors that fatigue and not pilot error is responsible for the crash of a new trans-Atlantic passenger plane, eerily forewarns of the mysterious crashes of the Comets in the 1950s. Those disasters were not attributed to metal fatigue until after the third one occurred.

Robert Byrne's novel *Skyscraper* is in the tradition of this work. The hero, an engineer who specializes in failure analysis, is called to New York City to determine why a 200-pound pane of glass has fallen out of the 66-story Zalian Building. The young engineer discovers numerous flaws in the structure, and Byrne, a civil engineer who was editor of a construction-industry trade journal for 15 years, complicates his plot with a variety of human-related causes of failure. These include design error, lack of objective inspection during and after construction, cost-cutting, building code violations, and attempts to use computers to design a lighter and more flexible structure than would otherwise have been attempted. Byrne shows how people who not only make honest mistakes but also condone dishonest coverups may contribute to structural failure. It is not that anyone, honest or dishonest, really wants a building to fall down. Rather, there seems to be a general disbelief that it could really happen because of any one defect.

Lists of causes of failures do not easily incorporate this human element, yet the motives and weaknesses of individuals must be taken into account in any realistic attempt to protect society from the possibilities of major structural collapse. This protection may ultimately have to come from a system of checks and balances in the construction industry, from legislatively empowered teams that investigate the causes of failures, from maintaining adequate margins of safety to insure that designs are not just barely sound, and from other human efforts.

Indeed, interest is growing in spreading information about failures. The new Architecture and Engineering Performance Information Center at the University of Maryland will serve as an archive of data on failures, and a recent report by the U.S. House Committee on Science and Technology recommended that the National Bureau of Standards be authorized to investigate disasters such as the 1981 collapse of the walkways in the Kansas City

Lasers cannot repeal the law of gravity or vaporize solar systems, at least not this year.

Hyatt Regency Hotel.

By pointing out what can go wrong, books such as Byrne's and Ross's make a positive contribution to improving structural safety. If only one design engineer or one construction manager sees an analogy that enables him or her to catch a flaw in a single project, such books have contributed to structural safety as surely as building codes or legislation. □

HENRY PETROSKI is director of graduate studies in civil and environmental engineering at Duke University. His book on engineering design and structural failure will be published by St. Martin's Press in 1985.

Laser Future

Laser: Supertool of the 1980s
by Jeff Hecht and Dick Teresi
Ticknor & Fields, $14.95

Reviewed by Jack D. Kirwan

One myth stemming from the Puritan ethic is the belief that for something to be profound, it must also be complicated and difficult to comprehend. The converse of that fallacy, of course, is that if a complex topic is presented clearly and lucidly, the explanation must be either simplistic or superficial. The latter idea may have gained currency in the not-so-old days when most writing on scientific topics was tough to comprehend, and part of the price of getting a technical education was slogging through the verbiage. Nowadays, it just isn't so.

Pournelle, Sagan, and Asimov—to mention three authors—can make complex themes understandable without jettisoning difficult concepts. And nobody has explained quantum physics more lucidly than Gerry Zukav in *The Dancing Wu-Li Masters*, although hard-core rationalists may wince at some of the philosophical conclusions he draws. *Laser* is in the same league. Jeff Hecht, managing editor of *Laser Focus*, and Dick Teresi, executive editor of *Omni*, present the fascinating phenomenon of the laser so well that some pecksniffs may disdain their work as mere popularization. However, after finishing this book, first issued in 1982 and recently reissued with a new introduction, any reader will know a great deal about both

the theory and practice of this remarkable technology.

The authors, who aim their message at intelligent nonspecialists, begin by defining a laser as "a device that produces a very special kind of light. You can think of it as a super flashlight. But the beam that comes out of a laser differs from the light in four basic ways." These qualities are intensity, directionality, coherence, and monochromaticity. If you can't define these terms precisely as they relate to the laser, this book is for you.

Laser may even come in handy for technologists who might otherwise find the basics too basic. Lasers are reminiscent of the fable of the blind men and the elephant: a lot of specialists understand what a neat tool the laser is for their field but may have only a vague idea of how it can be applied elsewhere. For example, a fusion specialist might not be too sure how a rock artist puts on a light show, or an eye surgeon might not be conversant with how lasers could be used to send solar power to Earth from satellites. Hecht and Teresi cover laser medicine, communications, weaponry, manufacturing, energy, uses in offices and supermarkets, and art forms. They also discuss the prospects for applying laser technology in fields such as genetic engineering, integrated optics, photochemistry, propulsion, and interstellar communications. Of course, exploring these uses involves more speculation than extrapolation: "If you want to know which efforts will work and which won't, you'll have to wait . . . few of the laser scientists we talked to were willing to go out on a limb without seeing the results, and we'll stick with them," say the authors.

Perhaps most important, Hecht and Teresi put laser technology in perspective. Lasers cannot provide immortality, repeal the law of gravity, or vaporize entire solar systems—at least not this year. And unlike the computer, bioengineering, and space colonization, the laser does not have the capacity to metamorphose the human condition. But it is a dazzling tool, one that "can cut through a two-inch-thick sheet of steel or detect a single atom. It can perform a task as dramatic as igniting a thermonuclear fusion reaction or as seemingly mundane as drilling a hole in a baby-bottle nipple." Hecht and Teresi have a fascinating subject and they cover it well. □

JACK D. KIRWAN is assistant editor of The Energy Journal *at the University of Arizona at Tucson.*

Since the U.S. military can't test its tools against actual nuclear explosions in the atmosphere, it has turned to an elaborate suite of simulations. But how good are they?

Simulating the Dreaded Day

BY DAVID M. KENNEDY

WITH apologies to Rogers and Hammerstein, there is nothing like a bomb. The blast, heat, and radiation from a nuclear explosion pose a threat so varied and powerful that nothing else can approach it. This fact, reassuring to most people, has been vexing U.S. government and military leaders since 1963, when the Limited Test Ban Treaty halted all nuclear tests, except those conducted underground, to prevent the spread of radioactivity. The military is therefore unable to test its tools directly, under "realistic" conditions, to determine how well they would bear up against the almost unimaginable violence of a nuclear attack.

Since the survivability of U.S. strategic nuclear forces—intercontinental ballistic missiles (ICBMs), bombers, and submarines—is at the heart of the concept of deterrence, any uncertainty is troubling. "Both we and any potential adversary must believe that powerful forces will survive a first strike and will retain operational capability in a nuclear environment, and that the command structure will exist to control these forces," says Lt. Gen. Richard K. Saxer, director of the Defense Nuclear Agency (DNA).

Military officials also worry about conventional battlefield gear that must function during a tactical, rather than an all-out, nuclear war. If this equipment isn't as resistant as possible, says T.K. Jones, deputy undersecretary of defense for strategic and theatre nuclear forces, "that simply increases the incentive for the Soviets to 'go nuclear' in a limited sense, with the idea that they could put our conventional forces out of business and then just go right through us."

From the DNA's headquarters in a sprawling, two-story brick building in northern Virginia, just outside Washington, D.C., the agency manages the government's nuclear-effects testing program. This includes efforts to ensure not only that weapons and communications systems will stand up to a nuclear attack, but also that U.S. offensive weapons will be able to reach their targets. The Soviet Union also has a comprehensive nuclear-effects program to bolster its military systems, which in some respects is more detailed than the U.S. program, says Jones. "The Russians are no slouches," he adds.

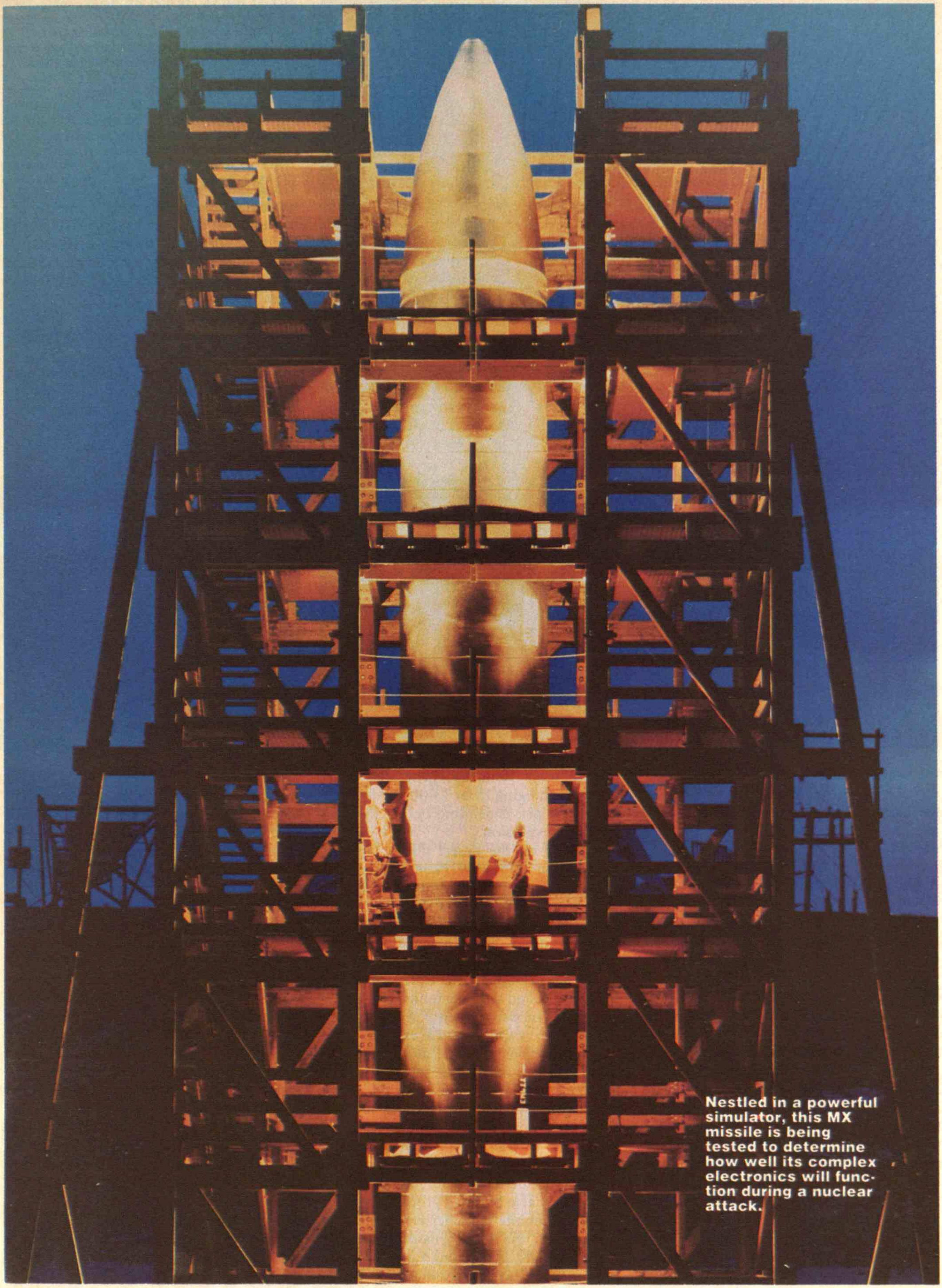
Underground nuclear testing provides a wealth of information about the impact of various kinds of radiation on a wide range of military equipment, according to Saxer. Indeed, he says the tests, conducted in tunnels drilled deep into mesas in the Nevada desert, remain "the most significant and indispensable aspect of our test capability." Three tests—code-named Misty Rain, Mill Yard, and Diamond Beech—are scheduled for fiscal year 1985.

But working underground has its drawbacks. The tests are of limited use in assessing equipment intended to function amidst the full panoply of nuclear effects—a deadly chaos that cannot be reproduced underground. For example, since the tunnels are relatively small, the bomb's blast must be baffled to keep it from destroying the testing gear before measurements can be made. (Even with baffling, most of the instruments are vaporized moments after the blast.) However, this changes what DNA scientists call the "fidelity of the shock wave" to a degree unacceptable for realistic testing of many systems, among them the hardened silos that protect missiles. Thus, ICBM silos, crucial to the nation's strategic deterrence, have never been challenged by the nuclear weapons they are intended to foil.

Other military equipment, such as tanks and the hardened mobile carriers planned for the Midgetman single-warhead ICBM, are designed to survive bombs that explode at least a few miles away. However, the complicated dynamics of a nuclear explosion as it travels that distance are so far impossible to mimic underground. In addition, the potent high-altitude electromagnetic pulse (EMP), produced when gamma rays from a nuclear blast 30 miles or so up interact with the outermost fringes of the atmosphere, cannot even in principle be generated underground. Yet EMP has emerged as a major threat to the electronics in a host of critical weapons and communications systems.

Underground testing also faces practical problems. The tests are expensive, costing perhaps $40 million to $60 million each. The close quarters restrict the size of the equipment that can be tested: "It's very

DAVID M. KENNEDY is a staff writer at Harvard University's John F. Kennedy School of Government and a regular contributor to Technology Review.

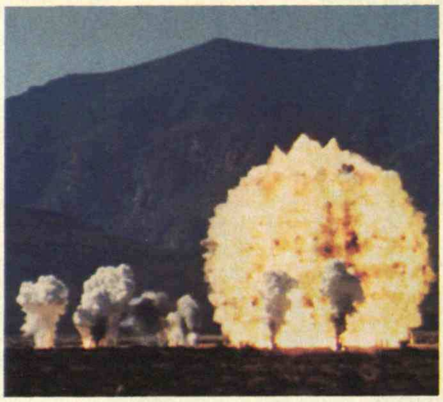


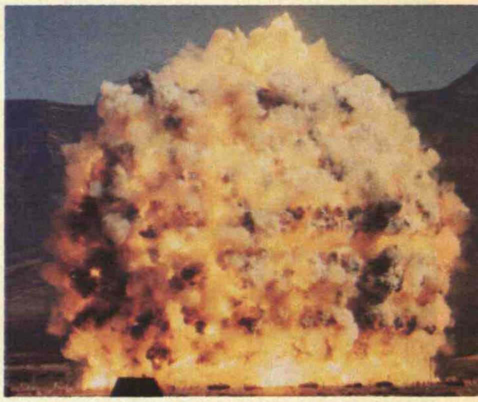
Nestled in a powerful simulator, this MX missile is being tested to determine how well its complex electronics will function during a nuclear attack.

PHOTOGRAPHS: DEFENSE NUCLEAR AGENCY

difficult to put a B-52 underground," says a DNA official. And since it takes a long time to drill the tunnels and prepare for each test, the DNA can conduct very few each year.

The DNA has therefore turned to an elaborate suite of laboratory and field simulations for testing resistance to "mock" nuclear effects. "We try to do as much as we can in these non-nuclear simulations," says Gordon Soper, a radiation-testing specialist at the DNA. "They are much less expensive, and in many cases can be done over and over again to test and retest important systems—all without having to use a real nuclear weapon." Indeed, researchers are now using simulations to test the durability of systems that will operate in situations ranging from outer space to the ocean's depths.





A Blast in the Desert

One such test rocked the desert at White Sands Missile Range south of Albuquerque in October 1983, only 3.5 miles from the Trinity site where the first atomic bomb exploded in 1945. The DNA called this test, code-named Direct Course, the "world's largest non-nuclear height-of-burst event"—one that simulates a nuclear air burst. Six hundred tons of high explosives—a mixture of ammonium nitrate and fuel oil, packed into a fiberglass sphere perched on a tower nearly 200 feet high—flashed into a fireball that rose in a classic mushroom cloud high into the still New Mexico sky.

Anything hit by the explosion's shock wave "would think it was hit by the blast from a 1-kiloton nuclear bomb," says Tom Kennedy, chief of the DNA's test division. By comparison, the bomb dropped on Hiroshima was about 12 kilotons. As it spread out from "ground zero," the DNA's blast had much the same "shape"—or pressure-versus-time characteristics—as would occur at the fringes of an air burst over a battlefield during a tactical nuclear war. (The DNA simulates ground bursts in the same way but without suspending the explosives on a tower.)

A bomb's blast is measured in pounds per square inch (psi) of pressure above atmospheric pressure—or "overpressure." Trucks implode at 5 psi, tanks at 10 psi; only buried structures can withstand more than 50 or 100 psi of overpressure. Direct Course, says Kennedy, generated overpressures ranging from 1,000 psi down to just a few psi, depending on the distance from the explosion.

Arrayed on the desert during the test were some 200 experiments, involving sundry military paraphernalia from all the U.S. armed services, the Federal Emergency Management Agency, the Department of Energy, and a handful of NATO countries. Although many of the experiments were classified, the DNA will admit to having tested aircraft, tanks, trucks, radar units, numerous army weapons systems, ship superstructures, portable communications systems, and emergency field shelters. Several dozen humanlike manikins, equipped with stress gauges in their heads and chests, stood in for soldiers. And scale-model submarines were berthed in a large pit filled with water—simulating a port, says the DNA—to see if they fared better submerged or afloat.

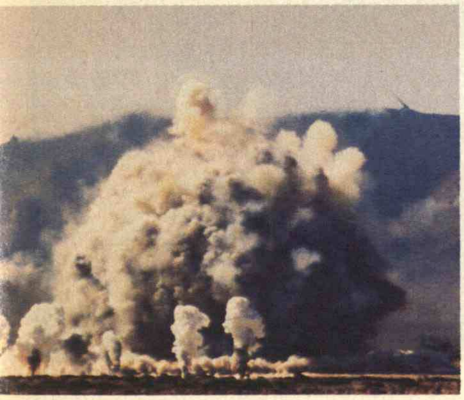
The blast also buffeted prototypes of the hardened mobile launcher envisioned for Midgetman, the small missile touted by many officials as the long-range solution to securing our land-based ICBM force. The DNA, the air force, and four aerospace companies—Boeing, General Dynamics, Bell Aerospace, and McDonnell-Douglas—deployed models of their proposed launchers, which varied in size from a one-tenth scale model to a full-scale cross-section.

The air force says the mobile launcher eventually deployed must be able to withstand overpressures of 25 to 30 psi; DNA's Kennedy calls this "the ragged edge of survivability." "Preliminary results," according to a statement from the Department of Defense, "indicate the feasibility of several of the designs." More sophisticated versions will be tested during the DNA's next high-explosive event scheduled for June. Indeed, the Department of Defense considers the speedy development of Midgetman so important that it has reserved a quarter of the desert area for the tests. Dubbed Minor Scale, this event will be a ground burst simulating an eight-kiloton nuclear explosion.

As powerful as these blasts are, however, they are not good enough for assessing the survivability of very hard systems, such as missile silos, because much of the energy from the explosions dissipates into the air. Today's silos are engineered to withstand overpressures of 2,000 psi, and researchers exploring "superhardened" silos are aiming at 50,000 or even 100,000 psi. "So what we use," says Kennedy, "is a technique that makes smaller explosions—which also means cheaper explosions—seem like much larger blasts typical of high-yield nuclear weapons."

The high-explosive simulation technique (HEST) can deliver "tens of thousands of psi overpressure for fifty-thousandths of a second, which is ample

This simulated air burst, equal to the power of a 1-kiloton nuclear bomb, buffeted a variety of military systems to test their durability. High-speed cameras caught the action. From left to right: Chemical plumes ignite just before detonation to help mimic the heat of a nuclear blast. Some 600 tons of explosives, packed in a sphere atop a tall tower, detonate. In milliseconds the blast enters its "popcorn-ball" stage. The awesome shock wave moves away from the explosion. And finally, the classic mushroom cloud rises into the New Mexico sky.



for our purposes," says Gene Sevin, assistant to the deputy director for science and technology at the DNA. "This allows us to simulate nuclear blasts of a few kilotons up to perhaps a few megatons." The DNA has used HEST, which was developed in the mid-1960s, to stress and strain every type of silo—from those upgraded in hardness for the Minuteman missile to those for the MX missile now proposed for deployment.

In HEST, a layer of explosives a few inches thick and 100 feet or more long is embedded beneath the ground, with the silo to be tested located under one end of the bed. "To save money, we generally use scale models of the silos, perhaps one-eighth to one-half actual size," Sevin notes. "But we're also careful to make them as realistic as possible." During a test, the researchers touch off the detonation at the far end of the bed so that the explosion's wavefront will sweep along the bed and pass over the silo's cap. "This mimics the behavior of a shock wave from an actual nuclear blast," says Kennedy. "It wouldn't be realistic to simply thump the top of the silo."

A nuclear blast also produces powerful ground shocks that follow the wavefront. These are at least partially simulated in HEST by peppering the ground around the silo with explosive charges that are triggered as the wavefront passes. Sevin says they are still trying to "fine tune" the ground shocks in HEST by gathering data on ground movements during a series of small underground tests.

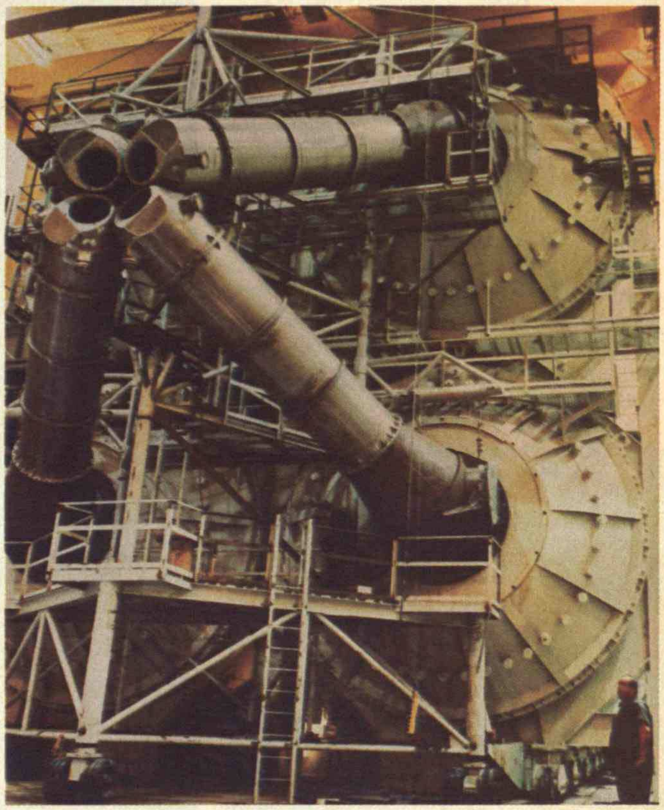
Checking the Pulse

When electromagnetic pulse—the brief burst of intense electromagnetic energy generated by nuclear explosions high above the earth—was first detected during early atmospheric tests, scientists considered it only a potential nuisance. But in 1962 events took a dramatic turn. Starfish, a detonation over Johnston Atoll, knocked out street lights and triggered burglar alarms 800 miles away in Honolulu. EMP's devastating impact on electronics systems has since become a major military concern. (*See "Strategic Command and Control: America's Achilles Heel" by Jonathan Tucker, August/September 1983, page 38.*) For example, the National Research Council reported last year that several large high-altitude nuclear explosions "might render unprotected equipment and systems inoperative over an area as large as the continental United States." Thus, the council concluded, it is "essential to protect electronics systems and to form some idea of how well they will withstand EMP."

The problem is especially troublesome because EMP does the most harm to advanced electronics. Modern weaponry and communications systems using solid-state circuits are extremely vulnerable to being disrupted or destroyed. Prospective systems using large-scale integration or very-high-speed integrated circuits—a major military priority—will be even more so. Designers can shield entire systems or crucial subsystems in elaborate metal cages that shut out EMP. However, any gaps in the shielding, such as leads, cables, antennae, or viewports, will admit EMP. Very fast circuit breakers or redundant electronics can protect these avenues—designers think they can, at least—but only a test can determine the success of the overall

Nuclear explosions high in the atmosphere produce an electromagnetic pulse (EMP) that can knock out electronics systems. This F-14 is being lowered onto an EMP simulator to test the fighter's "hardness."

Nuclear blasts also generate damaging gamma radiation. Aurora, a gamma-ray simulator named for the Roman goddess of dawn, has been used to test all major military systems (right).



"Both we and any adversary must believe that powerful forces will survive a first strike and will retain operational capability."

hardening measures. "You have to rely on simulators to indicate that you really got there," says John Pierce, a computer scientist at Stanford University who participated in the National Research Council's EMP study.

The DNA and the armed services use a number of EMP simulators. Trestle, a huge wooden structure located at Kirtland Air Force Base in New Mexico, can be used to test items as large as B-52 aircraft. The Advanced Research Experimental Simulator (ARES), also located at Kirtland, is suited for testing missiles. Empress is a barge-mounted simulator for testing ships. (A recent proposal by the navy to develop an even more powerful version of Empress to use in Chesapeake Bay set off a public furor.) And a Transportable EMP Simulator (TEMPS) is used to test stationary systems such as communications centers. The TEMPS recently went as far as Hawaii, where DNA researchers used it to test the hardness of a telephone switching station used to communicate with military forces in the Pacific.

Gamma rays generated by nuclear explosions can also knock out electronics systems. The effects of these are harder to counteract, since they do most of their damage at the molecular level in the microchips. They are also harder to simulate. In fact, gamma rays identical to those a bomb spews out can't be produced in the laboratory. Thus, Gordon Soper says DNA scientists must actually simulate a simulation—using powerful x-rays produced by a behemoth of a machine called Aurora.

Aurora generates x-rays in much the same way as a medical unit—by sending electrons into a metal plate. But the x-rays are extremely energetic and closely resemble the gamma rays emitted by a nuclear bomb. The machine beams these "threat-level" x-rays cum gamma rays at the equipment to be tested, which for safety's sake is contained in a vault with walls several feet thick and a 50-ton door.

The DNA says Aurora has been used to test all major military systems since its startup in 1971. However, it can only zap equipment up to about the size of the proverbial breadbox. "This means we have to test systems in pieces," Soper notes. But that doesn't guarantee survival of the as-

sembled system. "That's a crucial issue on the minds of many people who do this kind of nuclear-effects testing," he says. "We simply do what we can."

Nuclear explosions also release x-rays that pose a threat to electronics systems. These, too, prove difficult to simulate. Aurora produces x-rays that are much more energetic than those from a bomb, and the machine can't be "turned down" efficiently. Thus, most x-ray testing has been done during underground nuclear blasts. But Soper says that over the last several years, DNA scientists have made "quite a breakthrough in our ability to test in the laboratory a close approximation of the x-ray environment." The work is done in "puff-gas" facilities with names such as Casino, Blackjack, and Python. In these machines, electricity passes through tungsten or aluminum wires. The metals vaporize when the wires get very hot, and the resulting plasma radiates the desired bomblike x-rays as it cools.

But Are They Right?

These are but a few of the ways DNA researchers go about simulating the day everyone hopes will never come. But how reliable are the tests? The nuclear weapons community—virtually the only group familiar with the subtleties of the program—welcomes the results of the simulations and finds them useful. "I have high regard for the work these people are doing," says Jonathan Katz, an astrophysicist at Washington University who has done work for the DNA on the ill-fated MX "dense pack" deployment scheme and the Midgetman carrier. "I think they are doing a good job on a very difficult problem."

However, DNA specialists and skeptics alike worry about the realism of simulations. Radiation and EMP simulators, for example, generate pulses that aren't identical to the real thing, and there is even considerable uncertainty about the exact nature of EMP. EMP is known to reach incredible energy levels in perhaps ten nanoseconds, or ten-billionths of a second, and "all EMP simulators are thousands of times slower than that," says Kosta Tsipis, director of the Program in Science and Technology for International Security at M.I.T. But whether this means, as Tsipis believes, that the results from simulators are inaccurate is difficult to assess—the simulators are all scientists have to go on. Defense Undersecretary Jones takes this problem seriously enough to have initiated a search for entirely new ways to generate EMP, but he says he isn't optimistic about finding any.

Critics also cite the inability of simulations to study all of the effects of a nuclear blast simultaneously. Since simulations are imperfect to begin with, this removes them one step further from reality. A blast's shock wave would almost certainly shake loose carefully crafted EMP shielding, for example. Also, tests such as Direct Course lack a way to heat the entire overpressure zone, or even large portions of it, even though temperatures during a blast may reach 7,000° F. Structures weakened by heat would certainly be less able to hold their own against the shock wave. (Direct Course did employ four torches burning liquid oxygen and powdered aluminum at 4,000° to heat selected experiments, but most of the systems tested went without.)

Tsipis sums up his detailed assessment of simulations with one blunt judgment: "In a nuclear war," he says, "we don't really know what would happen." Yet he and others point out that current U.S. policy is geared toward developing the ability to use controlled, selective nuclear strikes as a response to nuclear attack. Military planners, says Daniel Stein of Princeton University, "see a protracted nuclear war as feasible, with plans and weapons to be chosen accordingly." But he wonders how this would be possible since "uncertainties are the *only* certainty" in nuclear war.

However, given the fact that the Limited Test Ban Treaty is secure—although one of DNA's responsibilities is maintaining facilities on Johnston Atoll to allow prompt resumption of atmospheric testing—simulations will continue. They provide the most concrete data the military can get, and they've been worked inextricably into the process of refining old weapons and communications systems and designing new ones. The Senate has also recommended that President Reagan resume negotiations with the Soviet Union on a comprehensive test ban treaty, supported by the past five U.S. presidents, that would prohibit even underground nuclear testing. This would make the role of simulations even more important. "There's always some new system being developed, some new process being designed. And testing stands as the key to their success," Soper reflects. "We certainly see no end in sight." □

Continued from page 13

that includes specially designed recreational and informational software, modified hardware packages, instructional support, and an on-line informational network tailored to the needs of the elderly.

No Substitute for Human Contact

In creating these new product lines, we must guard against uses of computer technology that isolate elderly people. As Raymond Nelson, emeritus professor at Case Western Reserve University, cautioned at a conference in 1981 on communications technology and the elderly, "Human-to-machine conversation . . . is liable to degrade the quality of human existence, not enhance it, especially for the elderly." To appreciate the reality of that risk, one need only reflect on the way harried parents have used television sets as an easy escape from the demands of caring for their children. I do not mean to suggest that for the very old, computer terminals could ever become a substitute for sustained, compassionate human contact. At the same 1981 conference, M.I.T. Professor Walter A. Rosenblith emphasized that "terminals themselves can generate new forms of loneliness . . . it is the interaction with fellow humans that seems to bring out in most of us optimal utilization of our information-processing capacities."

But the risks need not deter us from a prudent pursuit of the gains that could result from supplementing human contact with judicious use of technology. The development of computer applications that enrich the lives of the elderly would be a sound investment in the future.

As Nelson wisely urges, such development should proceed with "input at the planning and design stages from older individuals themselves." This collaboration can occur on a small scale through ad-hoc arrangements between fledgling companies and nearby institutions and agencies involved in the care of the elderly. It can also proceed on a large scale through cooperative ventures between major computer and software companies and national organizations such as the American Association of Retired Persons.

Information is never more crucial to our well-being than during our advanced years. We should begin applying all that we know about information technology to the needs of older generations. After all, we're not that far behind them. □

Continued from page 5

latter complacent. He then argues: "No wonder the public loses confidence in scientists." This account is misleading and ignores the media's contributions to public confusion.

On March 30, 1983, EPA released a report that stated: "The global warming is not likely to be prevented. Although [prevention] would require a worldwide consensus, responding to its consequences would not." The March 31 *Christian Science Monitor* quoted EPA Associate Administrator Joseph Cannon as saying that "a rise in sea level within the next 100 years of as much as eight feet cannot be ruled out." Most other newspapers failed to discuss the report because at the time there was a more interesting story at EPA: the ouster of every top official other than Mr. Cannon.

In the following six months, dozens of newspapers and wire services along the East and Gulf Coasts did carry stories about rising sea level and the greenhouse effect, but major newspapers and television networks did not. In early September, EPA released *Can We Delay a Greenhouse Warming?*, but again the press took little notice. However, on October 18, two days before NAS released its report, the *New York Times* announced on its front page that EPA had predicted the global warming report, and the television networks and other newspapers immediately picked up the story. With Anne Gorsuch gone, the media were once again eager to cast EPA as environmental crusaders taking on conservative skeptics, even though the two reports reached the same conclusions.

No wonder the public loses confidence in the news media!

Walter F. Bauer
Baltimore, Md.

Mr. Cowen's attempt to establish the EPA and NAS reports as two ends of a spectrum of opinion presumably serves your journalistic objectives, but it does a great disservice to both reports. Apart from early statements in the popular press that sensationalized the findings, the bulk of scientific opinion has been that the two groups come to remarkably similar conclusions on the topics they both studied. In fact, Dr. William Nierenberg, chairman of the NAS study group, has said that both reports conclude that:

☐ Increases in greenhouse gases are very likely to produce significant temperature rises by the middle of the next century.

☐ We need to expand our efforts to better understand the timing and effects of global temperature increases.

☐ No immediate action to curb the use of fossil fuels is needed (according to NAS) or would be effective in the medium term (according to EPA).

Even the estimates of sea-level rise in the next century are almost identical. Although the EPA report placed more emphasis on the role of greenhouse gases other than CO_2, the NAS report acknowledges their potential importance as well.

By characterizing the EPA report as alarmist and its release as a form of burlesque, Mr. Cowen has fallen far short of the standards of the two prestigious publications he serves.

Dale L. Keyes
Washington, D.C.

The writer is co-author of the EPA report, Can We Delay a Greenhouse Warming?

How to Slow the Oil-Price Roller Coaster

The world's reserves of oil that are producible at costs below today's prices are immense compared with current consumption. Yet the price of oil seems to ride a roller coaster, slipping slowly down until the time comes—apparently inexplicably—for a stomach-turning maneuver.

This apparently perverse economic behavior results from our panic responses to OPEC's sometimes unsteady but ultimately effective grip on the world oil market, says M.I.T.'s outspoken oil economist Professor Morris Adelman. OPEC may be an uneasy alliance among unlikely partners "whose normal form of discourse is mostly violence and conspiracy," says Adelman, but its survival is hardly in doubt. Its members have much to gain and little to lose from its continuing power—and the world would have much to lose in its demise.

When will come the next move toward higher prices? Any time the cartel overreacts in cutting back production to prop up prices, said Adelman at an M.I.T. symposium last fall. Late in this decade, answered Jack W. Wilkinson, chief economist for Sun Co., whose reasoning goes like this: With the present oil glut, OPEC nations are investing little or nothing in developing new reserves; their present maximum sustainable capacity is about 28 million barrels a day, while present production is only about 18 million. Without new development, OPEC capacity will drop—perhaps below demand—by the end of the decade, as some of today's wells are depleted.

When that happens, the price of oil will surely go up—indeed, there are lots of what systems analysts call elements of "positive feedback" in energy supply and demand that will work together to effect a sharp increase when supply and demand exchange positions on the world market.

Shutting down a business for lack of oil to fire its boilers is far more costly to owners and workers than paying a \$1-a-gallon surcharge on the next fuel delivery. When there is plenty of oil there are fewer incentives to invest in conservation and non-oil alternatives that will be needed in a time of scarcity. When oil is cheap we tend to build up our stock of energy-guzzling devices such as high-performance cars.

Though many consumers have switched from oil to coal and more will, there is no substitute for petroleum-derived liquid fuels in transportation. It's simply not realistic to expect synthetic liquids from coal to reduce our dependence on oil for at least two decades, says Malcolm A. Weiss, a synfuels expert who is co-director of the M.I.T. Energy Laboratory. To make gasoline from coal (using today's technology) competitive with gasoline from crude oil without subsidies, the price of crude would have to be over \$60 a barrel—more than double today's figure, says Weiss.

But must we ride the roller coaster of crisis-driven prices powered by the sense of panic that grips an American motorist upon seeing a hastily scrawled "No gas!" sign? The oil price shock of 1973 was triggered by cuts in OPEC production of about 5 percent—too small by far to account for their effect on price, says Adelman. There was no shortage when prices jumped in 1979—only panic. Adelman thinks today's Strategic Oil Reserve of about 400 million barrels is quite adequate to defuse a crisis before it gains momentum. Only one key element is missing, says Adelman—a plan to use the reserve without advance warning, which crises never give.—*John Mattill* □

Password Pirates

With more and more data being stored in computers, more and more people—sometimes unauthorized—want access to them. Hence increasing emphasis on passwords—the identifications that authorized users must give computers before receiving information from their databanks. Here are some tips from the M.I.T. Information Processing Services for choosing passwords to prevent piracy:

Don't use . . .

□ Your name—first, middle, last, initials, or backward.
□ Any common name.
□ Your userid (user identification), or your userid spelled backward.
□ Part of your userid or name.
□ The name of a close relative, well-known pet, or close friend.
□ Fewer than four characters to define your password.
□ Your phone or office number, your birthday, your anniversary.
□ Any word in a dictionary.

Do choose . . .

□ Something that is easy for you to remember.
□ A deliberate misspelling.
□ An odd character in an otherwise familiar term.

In short, be creative and imaginative when choosing a password, says IPS. Change it frequently, and don't talk about your method to anyone. A bit of discretion now can save you lots of grief later. □

Research on Power

Confronted by unprecedented technological challenge, the U.S. electric power industry continues to rely on research and development efforts that are "disaggregated, episodic, and *ad hoc*," says President Paul E. Gray of M.I.T. He describes the current budget of the Electric Power Research Institute, the industry's cooperative research and development organization, as "completely inadequate."

Speaking to the Edison Electric Institute's 1984 convention in Boston, Dr. Gray listed four challenges for the nation's electricity generators:

□ Decreased rates of growth and increasing costs.
□ Continued "devastating" impact of regulation.
□ Growing public concern about the environmental impact of electric generation.
□ Lack of confidence by the public—and to some extent by the industry, as well—in nuclear technology.

An industry with \$130 billion in annual revenues and confronting problems such as these ought to do better than EPRI's \$300 million cooperative research program, said Gray. "Even the short-term requirements of the industry cannot be met," he said, "and the longer-term needs are simply not addressed." □

Automatic Finishing

A new adaptable tool-guide mechanism developed by Professor Haruhiko Asada and Yuzo Sawada in the Mechanical Engineering Department can make possible automatic finishing operations such as grinding and deburring.

Most such operations are now done by hand, Asada and Swada told a meeting of the American Society of Mechanical Engineers in Cambridge late last fall, because "present-day robots cannot locate tools accurately in the face of severe load conditions." The new tool guide follows the work surface accurately with a computer control system powerful enough to guide finishing tools. □

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